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MIDDLE CREEK DAM REHABILITATION

LOAN APPLICATION REPORT

April 1, 1987

HKM Associates, Engineers/Planners

Billings & Libby, MT/Sheridan, WY

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MIDDLE CREEK DAM REHABILITATION

LOAN APPLICATION REPORT

April 1, 1987

HKM Associates, Engineers/Planners
Executive Plaza, Airport Industrial Park
P.O. Box 30318
Billings, MT 59107
(406) 245–6354

Billings & Libby, MT/Sheridan, WY

Prepared for :

MT Department of Natural Resources & Conservation

HKM

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DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

TED SCHWINDEN, GOVERNOR

1520 EAST SIXTH AVENUE

STATE OF MONTANA

DIRECTOR'S OFFICE (406) 444-6699

HELENA, MONTANA 59620 2301

RECEIVED
APR - 2 1987
KM ASSOCIATES

April 1, 1987

B. E. Martin
Regional Director
U. S. Bureau of Reclamation
Missouri Basin Region
P.O. Box 36900
Billings, MT 59107-6900

Dear Mr. Martin:

I am pleased to submit the enclosed final application for financial support through the Small Reclamation Projects Act. If granted, the funding would enable us to bring the Middle (Hyalite) Creek Dam into conformance with modern dam design standards and provide a safe structure. As discussed in the application report, this will involve constructing an emergency spillway, improving the principal spillway, and raising the dam embankment and reservoir water surface.

Study findings presented in this report show that the project is feasible from both an engineering and economic standpoint. Water needed for the enlarged project is available in the source of supply and the department has applied for the necessary water right in accordance with state law. The effect of this new right on prior water rights, particularly those held by the U.S. Bureau of Reclamation, is presently the subject of a lawsuit. The state is currently meeting with your agency to discuss the means whereby we would obtain water for the proposed project expansion if the federal government prevails in this lawsuit.

Total cost of this project has been estimated to be $5,195,900. As discussed in the report, funding would be derived from three sources, a state contribution of $1,298,975, a federal grant of $775,000 and a PL 84-984 loan of 3,121,925. In finalizing the report, project costs were refined and therefore differ from those approved by the Board of Natural Resources and Conservation in the resolution presented in our application. Accordingly, these increased project costs will be resubmitted

to the Board for consideration. At this time, we expect Board approval of these revised cost figures.

In accordance with procedures under the Small Reclamation Projects Act, we request that this application be submitted to the Secretary of Interior for final consideration. If we may provide you anything else in this regard, please do not hesitate to contact me.

Sincerely,

Larry Fasbender

Larry Fasbender
Director

Enclosure

MIDDLE (HYALITE) CREEK DAM

LOAN APPLICATION REPORT

Prepared For:

Montana Department of Natural Resources
and Conservation
32 South Ewing
Helena, Montana 59620

Prepared By:

HKM Associates
P.O. Box 31318
Billings, Montana 59107

April 1, 1987
8M087.121/WPWATRES221

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LIST OF ABBREVIATIONS

AF	-	Acre-feet
APO	-	Areawide Planning Organization
calc.	-	Calculated
cfs	-	Cubic feet per second
Const.Adm.	-	Construction Administration
CY	-	Cubic yard
°F	-	Degrees fahrenheit
Dia.	-	Diameter
DFWP	-	Department of Fish, Wildlife and Parks
DNRC	-	Department of Natural Resources and Conservation
EFF	-	Efficiency
fps	-	Feet per second
Ft	-	Feet
g	-	acceleration of gravity
GPCD	-	Gallons per capita per day
gpm	-	Gallons per minute
H	-	Horizontal
HP	-	Horsepower
In.	-	Inch
KW	-	Kilowatt
KWH	-	Kilowatt hour
Lbs	-	Pounds
LF	-	Lineal foot
LS	-	Lump sum
Max.	-	Maximum
MCWUA	-	Middle Creek Water Users Association
MDHES	-	Montana Department of Health and Environmental Sciences
MGY	-	Million gallons per year
mg/l	-	milligrams per liter
Misc.	-	Miscellaneous
M&I	-	Municipal and industrial
ml	-	milliliter
MWRB	-	Montana Water Resources Board
N	-	North
NGVD	-	National Geodetic Vertical Datum
No.	-	Number
NTU	-	Nethelometric turbidity unit
OM&R	-	Operation, maintenance, and repair
pH	-	A measure of hydrogen ion concentration
%	-	Percent
P.L.84-984	-	Public law 84-984, Small Reclamation Projects Act
PMF	-	Probable maximum flood
Recom.	-	Recommended
RIM	-	Recreational Information Management
SWCB	-	State Water Conservation Board
USBR	-	U.S. Bureau of Reclamation
USFS	-	U.S. Forest Service
USFWS	-	U.S. Fish and Wildlife Service
USGS	-	U.S. Geological Survey
V	-	Vertical
WS	-	Water surface
Yr	-	Year

PREFACING MATERIALS

Resolution No. 1

RESOLUTION APPROVING APPLICATION REPORT AND AUTHORIZING THE FILING OF APPLICATION FOR LOAN AND GRANT UNDER PUBLIC LAW 84-984, AS AMENDED

WHEREAS, the Department of Natural Resources and Conservation (DNRC), State of Montana, desires to secure a Federal loan under the Small Reclamation Projects Act, P.L. 84-984, as amended, and has authorized its consulting engineers, HKM Associates, Billings, Montana, to prepare a feasibility report in support of an application for said loan to finance rehabilitation of the principal spillway, construction of an emergency spillway, raise the dam ten feet and raise the reservoir water level 8.2 feet of the Middle (Hyalite) Creek Dam, Gallatin County, Montana; and

WHEREAS, said consulting engineers have prepared a supporting Loan Application Report, as required under the Small Reclamation Projects Act, entitled, "Middle (Hyalite) Creek Dam Rehabilitation Feasibility Study, dated February, 1985; and

WHEREAS, the Loan Application Report proposes a project having a total estimated cost of $5,054,000 of which $3,463,000 should be obtained by a loan from the Federal Government under the provisions of P.L. 84-984 as amended, to be repaid within a 40-year period; and

WHEREAS, the Department pursuant to section 85-1-202 MCA must obtain the approval of the Board of Natural Resources and Conservation (Board) prior to mortgaging or creating a lien against the Middle Creek Water Project;

NOW, THEREFORE, BE IT RESOLVED that the Board hereby approves and authorizes the Department to make application to the U.S. Department of the Interior, Bureau of Reclamation, for said loan, and to mortgage and/or otherwise create a lien on said property covered by the Middle Creek Dam Water Project;

BE IT FURTHER RESOLVED that a copy of this resolution be transmitted to the U.S. Department of the Interior, Bureau of Reclamation, with the application report,

PASSED, ADOPTED AND APPROVED by the Board of Natural Resources and Conservation at a regular meeting of said Board held on January 9, 1987 by the following roll call vote:

AYES: 6

NOS: 0

ABSENT: 1 - Hash

ATTEST:

Chairman of the Board

Larry Fasbender, Director
Department of Natural Resources
and Conservation

I HEREBY CERTIFY THAT I am the Director of the Department of Natural Resources and Conservation, and that the foregoing resolution was duly adopted by the Board at a regular meeting thereof duly held at Helena, Montana on 9th day of Jan. at which meeting a quorum of said Board was at all times present and acting.

IN WITNESS WHEREOF, I have set my hand and seal of the Department this 9th day of Jan. '87.

Larry Fasbender, Director
Department of Natural Resources
and Conservation

State of Montana
Office of the Governor
Helena, Montana 59620
406-444-3111

TED SCHWINDEN
GOVERNOR

February 5, 1987

Mr. Bill E. Martin
Regional Director
Bureau of Reclamation, USDI
Missouri Basin Region
P. O. Box 36900
Billings, Montana 59107

Dear Mr. Martin:

I have reviewed the final loan application report for the Middle Creek Dam Rehabilitation Project and want to advise you of my support for this proposed undertaking. State support is further demonstrated by our effort to obtain an appropriation from the current Legislature for $496,000 in state funds to assist with this project.

This project must be undertaken to repair an unsafe dam so as to protect people and property. It will also ensure that an adequate supply of water is available for the City of Bozeman and the agricultural lands of the Gallatin Valley.

I concur with the findings of the Department of Natural Resources and Conservation regarding the economic feasibility of the project. In addition, the water rights held by the state for the existing project appear to be in good standing, and claims have been filed for these rights in accordance with the statewide adjudication program. A new water right permit for enlarging the project has been applied for. As you know, a lawsuit has been filed regarding the water rights of the US Bureau of Reclamation and others. The state is currently meeting with the Bureau to discuss how the Department of Natural Resources and Conservation would obtain water for the proposed project expansion if the federal government prevails in this lawsuit.

I hope you will favorably consider the Small Reclamation Projects loan application for the Middle Creek Dam Rehabilitation Project as submitted by the Montana Department of Natural Resources and Conservation.

Sincerely,

TED SCHWINDEN
Governor

cc: Larry Fasbender, Director, DNRC

United States Department of the Interior
FISH AND WILDLIFE SERVICE

MAILING ADDRESS:
Post Office Box 25486
Denver Federal Center
Denver, Colorado 80225

STREET LOCATION:
134 Union Blvd.
Lakewood, Colorado 80228

IN REPLY REFER TO:
FWE/ES
MAIL STOP 60120

RECEIVED
JAN 26 1987
MONT. DEPT. of NATURAL RESOURCES & CONSERVATION

JAN 20 1987

Mr. Robert A. Clark
Engineering Bureau
Department of Natural Resources
and Conservation
1520 East Sixth Avenue
Helena, Montana 59620

Dear Mr. Clark:

This letter responds to the Department of Natural Resources and Conservation's December 19, 1986, request to the Regional Director for comment on the proposed Middle Creek Dam Rehabilitation Project.

The U.S. Fish and Wildlife Service's (Service) detailed review comments on the Middle Creek Dam Rehabilitation Environmental Assessment were previously provided to the Department of Natural Resources and Conservation by copy of a December 19, 1986, letter to the U.S. Forest Service from the Field Supervisor of our Billings Field Office. The major remaining unresolved issue identified by the Service during this review pertains to the need of assuring a minimum pool for the protection of the Middle Creek Reservoir arctic grayling population. The Service is not in agreement with the minimum pool provisions currently proposed for the project.

Several potential mechanisms to provide for a minimum pool were identified in the Service's December 19, 1986, letter, including the possibility of utilizing a Small Reclamation Projects Act (Public Law 84-984) fish and wildlife grant. I understand that a grant of approximately $384,000 would be required to purchase storage rights for the minimum pool. Since the arctic grayling has been identified as a "Species of Special Emphasis" in Region 6, and has otherwise been variously recognized as a sensitive species by other entities, the need to minimize threats to the species may justify the cost of purchasing storage for a minimum pool to protect this population. The Billings Field Office is currently attempting to evaluate this possibility.

If a minimum pool can be secured, either with a fish and wildlife grant as mentioned above or through some other mechanism, the U.S. Fish and Wildlife Service's concern regarding this project would be alleviated.

The Service concurs with the determination that the project as proposed will not affect endangered species or their critical habitat.

Further questions regarding the Service's concerns should be addressed to the Field Supervisor, U.S. Fish and Wildlife Service, Billings, Montana.

Sincerely,

John D Green

John D. Green
Acting Assistant Regional Director,
Fish and Wildlife Enhancement

cc: Director, MDFWP, Helena, MT
Regional Coordinator, MDFWP,
Bozeman, MT
Regional Director, USBR, Billings, MT
Ecological Services Field Supervisor,
USFWS, Billings, MT (61410)
Endangered Species Field Supervisor,
USFWS, Helena, MT (61130)

MONTANA INTERGOVERNMENTAL REVIEW CLEARINGHOUSE
REVIEW AND COMMENT FORM

RECEIVED
JAN 16 1987
MONTANA DEPT. OF NATURAL RESOURCES & CONSERVATION

Applicant: MT Department of Natural Resources and Conservation
Water Resources Division, Engineering Bureau
Attn: Robert Clark, Engineer
Phone:
Address: 1520 East Sixth Avenue, Helena, MT 59620

Subject: Draft Middle Creek Dam Environmental Assessment

Clearinghouse SAI No. MT861215-270-S

YOUR COOPERATION IS REQUESTED IN COMPLETING YOUR REVIEW AND RETURNING THIS FORM WITH YOUR COMMENTS TO THE ABOVE ADDRESS, WITH A COPY TO THE CLEARINGHOUSE, NO LATER THAN January 15, 1987

	YES	NO	COMMENTS
Is this proposal consistent with the plans, goals and objectives of your agency?	X		If minimum pool & mitigation for loss of grayling spawning habitat are provided.
Does the proposed action conflict with any applicable statute, order, regulation or rule with which you are familiar?		X	
Does this proposal overlap, conflict or duplicate other existing programs or agencies?		X	

Describe any suggestions or means of improving or strengthening the proposed plan.

A more clearly defined commitment by the Dept. of Natural Resources and Conservation to mitigate loss of grayling spawning habitat is necessary for the finding of no significant impact determination.

Please convey your general conclusion by checking the appropriate response(s).

____ Proposal is supported.
X Support only with conditions described below.
____ Non-supportive for the reasons described below.
____ Additional information is desired as described below.
____ No comment on this proposal.

REMARKS: See attached letter

Reviewer: James W. Flynn
Title: Director
Address: 1420 East 6th Avenue
Phone: 444-3186
Signature: James W. Flynn
Date: January 13, 1987

Return to Applicant listed above, with a copy to:

Montana IGR Clearinghouse
Lt. Governor's Office, Attn: Room 210
State Capitol
Helena, MT 59620

Montana Department
of
Fish, Wildlife & Parks

8695 Huffine Lane
Bozeman, MT 59715

December 19, 1986

Mr. John Dolan
Bozeman District Ranger
Gallatin National Forest
601 Nikles
Bozeman, MT 59715

Dear John:

We have recently reviewed the Middle Creek Dam EA and have the following comments.

In general, we believe the EA incorporates the concerns that we raised at the November 20, 1986 task force meeting. We do, however, continue to have concerns regarding the grayling mitigation proposal.

The grayling mitigation proposal describes the methods and scope of work of the proposal and assumes that the efforts will be successful. While we believe that the proposal does have excellent probability of creating in-kind, in-place spawning habitat for grayling, there is the potential of failure. Since the FONSI is dependent on successful mitigation, there needs to be a clearly defined commitment by the DNRC to successfully mitigate if the existing proposal is not successful.

The discussion of minimal pool on p. 10 is a vast improvement over earlier discussions. Clearly, the maintenance of a minimum pool is necessary to preserve the grayling population. While the proposal does not offer absolute guarantee of a minimum pool no smaller than 1150 acre feet, we believe that the history of the watershed suggests that we can maintain a minimum pool of 1150 acre feet. We believe that the proposal to call a negotiating meeting between the water users and the Middle Creek Environmental Task Force if conditions suggest the possibility of dropping below 1150 acre feet is a good one. This

type of a negotiating session will allow everyone, including the residents of Bozeman, to understand the tradeoffs between municipal water use and retaining water in the reservoir for the grayling population.

Thank you for the opportunity to comment on the EA.

Sincerely,

LeRoy Ellig
Regional Supervisor

LE:jtb

RECEIVED
JAN 28 1987
HKM ASSOCIATES

RECEIVED
JAN 23 1986
MONTANA DEPT. OF NATURAL
RESOURCES & CONSERVATION

Jan. 16, 1986

Mr. Robert A. Clark
Design Engineer
Engineering Bureau
Dept. Natural Resources
1520 East Sixth Ave.
Helena, Mt. 59620

Dear Bob:

The Middle Creek Water Users' Association will accept the four dollar ($4.00) per acre foot repayment charge on the loan through the Small Reclamation Projects Act, for the repair project as planned by the State Dept. The O & M assessment will be set by the Directors of the Middle Creek Water Users' Association.

The directors would like a distinction made between the old and new water rights when this project is completed. The old or existing rights would have first priority when necessary.

Some of the stockholders and directors would like a clarification of the term "Payment capacity" or no payment capacity as used in the PAYMENT RESOURCES section on the last page of the small blue summary booklet handed out at the annual meeting in October.

Thank you for your attention to these matters.

Sincerely,

Richard J. Boylan

Richard J. Boylan, President
MIDDLE CREEK WATER USERS ASSOC.

b/d

THE CITY OF BOZEMAN
411 E. MAIN ST. P.O. BOX 640 PHONE (406) 586-3321
BOZEMAN, MONTANA 59715-0640

January 9, 1985

Richard L. Bondy, Chief Engineer
Department of Natural Resources
and Conservation
State of Montana
32 South Ewing
Helena, MT 59601

RECEIVED
JAN 10 1985
MONTANA DEPT. OF NATURAL
RESOURCES & CONSERVATION

Dear Mr. Bondy:

This letter is in response to your letter of December 18, 1984, to Mr. Richard C. Holmes regarding the expansion of Middle Creek Dam (Hyalite Reservoir).

Enclosed is a copy of the January 7, 1985, City Commission Minutes pertaining to this item. The Bozeman City Commission voted unanimously to express an interest in purchasing the additional water as a result of the expansion of the Middle Creek Dam for municipal and industrial use. The City understands approximately 2,337 acre feet of water would be available. Further, the City expresses a desire to enter into a contract with DNRC to fund both the expansion of this facility and the construction of the existing facility. It is understood that costs for this project are estimated to be $32 an acre foot of water per year for forty years and that the DNRC is pursuing grant requests which could reduce the $4.1 million cost of the facility improvement to approximately $2.6 million--upon which the $32 acre foot costs are figured.

The City Commission stipulated that:

1. If the project costs change significantly that the matter would be brought before the City Commission; and

2. The DNRC keep the City informed about all matters relating to this project.

Hope this meets your needs. If you have any questions, please contact me.

Sincerely,

Jim Wysocki
City Manager

JEW/lh
Enclosure

CLEAN AIR AND WATER CERTIFICATION

The applicant certifies as follows:

(a) Any facility to be utilized in the performance of this proposed contract has ( ), has not (X), been listed on the Environmental Protection Agency List of Violating Facilities.

(b) It will promptly notify the contracting officer, prior to award, of the receipt of any communication from the Director, Office of Federal Activities, Environmental Protection Agency, indicating that any facility which it proposes to use for the performance of the contract is under consideration to be listed on the EPA List of Violating Facilities.

(c) It will include substantially this certification, including this paragraph (c), in every nonexempt subcontract.

Department of Natural Resources and Conservation
Applicant (name of irrigation district, water district, etc.)

By (signature): Larry Fasbender
Title: Director
Date: 1-29-87

U.S. DEPARTMENT OF THE INTERIOR
ASSURANCE OF COMPLIANCE
(TITLE VI, CIVIL RIGHTS ACT OF 1964)

The Dept. of Natural Resources and Conservation (hereinafter called "Applicant-Recipient")
(Name of Applicant-Recipient)

HEREBY AGREES THAT IT will comply with Title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Department of the Interior Regulation (43 CFR 17) issued pursuant to that title, to the end that, in accordance with Title VI of that Act and the Regulation, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives financial assistance from U.S. Bureau of Reclamation
Bureau or Office
and Hereby Gives Assurance That It will immediately take any measures to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by Bureau of Reclamtion,
Bureau or Office
This assurance obligates the Applicant-Recipient, or in the case of any transfer of such property, any transferee for the period during which the real property or structure is used for a purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance obligates the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance obligates the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by Bureau of Reclamation.
Bureau or Office

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the bureau or office, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Appliacnt-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall reserve the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, it's successors, transferees, and assignees, and the person or persons whose signature appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

1-29-87
Dated

Department of Natural Resources and Conservation
Applicant-Recipent

By: Larry Fasbender
(President, Chairman of Board or authorized Official)

1520 E. Sixth Ave. Helena, Mt 59620-2301
Applicant-Recipents Mailing Address

United States
Environmental Protection
Agency

Region 8, Montana Office
Federal Building
301 S. Park, Drawer 10096
Helena, Montana 59626-0096

RECEIVED
JAN 19 1987
MONT. DEPT. of NATURAL
RESOURCES & CONSERVATION

REF: 8MO

January 16, 1987

Robert A. Clark
Engineering Bureau
Department of Natural Resources
and Conservation
1520 E. Sixth Avenue
Helena, Montana 59620

Re: Middle (Hyalite) Creek Dam
Rehabilitation Project
Environmental Assessment

Dear Mr. Clark:

EPA has reviewed the above-referenced document. The Agency agrees with the need for rehabilitation to reduce possibility of dam failure. EPA would like to recommend that consideration be given to installation of dikes and water diversions to reduce the area exposed at the head end of the reservoir during drawdown. These efforts at the upper end of Canyon Ferry Reservoir significantly reduced problems with blowing dust and also provided excellent habitat for wild game, particularly migratory waterfowl.

Thanks for the opportunity to review and comment on this proposed project.

Sincerely,

John F. Wardell

John F. Wardell, Director
Montana Office

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
BOZEMAN RANGER DISTRICT
601 NIKLES, BOX C, BOZEMAN, MT 59715
(406) 587-6920

Reply to: 2720

Date: April 6, 1987

Bob Clark
MT Department of Natural Resources and Conservation
1520 E. 6th Avenue
Helena, MT 59620

Dear Bob:

As you requested, we reviewed the figures pertaining to recreation visitor use which the Forest Service provided for you in the 1985 Feasibility Study for the Middle Creek (Hyalite) Dam. Specifically, you asked us to confirm the following:

- Road count of 16,500 visitor days to reservoir;
- Our estimate of the percentage of increased use following completion of the road reconstruction project currently in progress (we estimated that recreational use in the drainage would increase by 25%);
- Dollar values which were estimated to represent a "willingness to pay" figure for fishing and camping on the National Forest.
- Forest Service estimated costs of recreational facility maintenance for those facilities directly associated with the reservoir (mainly Hood Creek and Blackmore Campgrounds). We estimate that our annual maintenance and operating costs for these developed recreation sites $6500; the periodic cost of heavy maintenance, repair and replacement of facilities is estimated to be approximately $23,000 per decade.

With the exception of the Road Count figure, each of the figures presented above is an estimate. These estimates are based on our knowledge of the area, and the present and projected levels of use for the area. We use these figures for all project planning efforts, and support the DNRC's use of the same figures for their project planning work.

If you have additional questions about these estimates, please call Nan Christianson at 587-6920.

Sincerely,

Nan Christianson

for JOHN J. DOLAN
District Ranger

cc: Orrin Ferris, HKM Associates, Billings, MT

SUMMARY

MIDDLE (HYALITE) CREEK DAM
REHABILITATION FEASIBILITY STUDY

LOCATION

Middle Creek Dam is located on Hyalite Creek approximately 14 miles south of Bozeman, Montana in Gallatin County. The dam, reservoir and contributing drainage are within the boundary of the Gallatin National Forest.

ORGANIZATION

Middle Creek Dam is owned by the state of Montana and is administered by the Water Resources Division, Department of Natural Resources and Conservation (DNRC). The Middle Creek Water Users Association (MCWUA) contract with DNRC for storage water. The MCWUA is responsible for repaying capital investments and operating and maintaining the dam in exchange for release of storage water from the dam. The financial status of the MCWUA is excellent. O&M assessments are less than $1.00/AF and most debt is paid.

PLAN

Purpose

The spillway capacity of Middle Creek Dam does not meet present dam safety standards. A breach of the dam embankment could occur as a result of overtopping during a large flood event. Damages from the resulting flood could exceed $30 million plus the cost of repairing the dam. The purpose of this rehabilitation is to bring the dam up to present dam safety standards and provide additional storage capacity.

Physical Works

The principal project features are:

1. An earthen auxiliary spillway excavated in the left abutment, which has a base width of 530 feet wide at the crest transitioning to 37 feet wide at its end.

2. Enlargement of the dam embankment by 10 feet using earth reinforced structure in the center of the dam and conventional earthfill on the ends.
3. Increase the normal water surface by 8.2 feet (from top of existing flashboards), enlarging the active reservoir capacity from 8,267 AF to 10,184 AF providing an additional 1,917 AF of storage. All of the storage not presently contracted (2,334 AF) will be allocated to municipal use.
4. Provision of an inlet weir and concrete chute liner in the existing spillway, a new stilling basin, and a channel and dike leading to a new drop structure to Hyalite Creek. The existing bridge will be replaced.
5. Riprap of the outlet conduit discharge area and minor improvements to the outlet works system.
6. Relocation of campground facilities, boat ramps, roads and other facilities affected by the rehabilitation.

Project Costs

Principal Spillway	$ 748,200
Auxiliary Spillway	342,000
Dam Enlargement	1,324,900
Access Roads	242,900
Environmental Mitigation	103,000
Subtotal	$2,761,000
Contingencies	690,300
Project Cost Inflation 1986-1990	345,100
Engineering and Administration	531,500
Interest During Construction (Municipal & Excess Lands Share)	98,000
Water Rights	10,000
State Construction Administration	64,000
Lendor Participation	80,000
Archeology	10,000
Construction Cost	$4,589,900
State Project Administration To-Date	106,000
Loan Application Report	500,000
Total Project Cost	$5,195,900

FUNDING PROPOSAL

Loan (40-year repayment)		$3,121,925
Grant (Federal)		775,000
State Contribution		1,298,975
Water rights	$ 10,000	
State Construction Administration	64,000	
State Project Admin. To-Date	106,000	
Feasibility Report	500,000	
Filing Fee	5,000	
Grant (State)	496,000	
Bond (Financed by State)	107,975	
Other (Archeology)	10,000	
Total Project Cost		$5,195,900

LAND

Service Area	14,912 Acres	
Irrigated Area	8,950 Acres	
Land Use		
Alfalfa - Grass Hay	37.5%	
Barley	22.5%	
Winter Wheat (Dryland)	15.0%	
Pasture, Subirrigated	15.0%	
Summer Fallow	7.5%	
Homestead Etc.	2.5%	
Interest-bearing Lands (Under P.L. 84-984 Program)		
Excess Land	465 Acres	Bears interest
Small Tract Lands	177 Acres	Bears interest
Commercial Irrigation	8,308 Acres	Does not bear interest

WATER

Supply (Average Year)

	Acre-Feet
Reservoir Inflow (May & June)	18,000
Reservoir Direct Flow Bypass (May & June)	1,000
Storable Flow (May & June)	17,000
Reservoir Yield (9 of 10 years)	10,200

Water Use (year 40)

Supplemental Irrigation	5,005
Municipal (City of Bozeman and Small Tracts)	5,179

Assuming that the City of Bozeman grows in population from its present 22,000 to 35,000 by year 2020 and the efficiency of the city's system is improved 20%, the additional 2,334 AF of storage provided by this project will satisfy the needs of the city. The city currently holds 2,805 AF of storage in Hyalite Reservoir. Estimated yield of rights held by the city from other sources (Lyman Creek and Bozeman Creek) provide 5,462 AF of water.

Water Rights

Storage rights held by the state of Montana in Hyalite Reservoir have a priority date of July 12, 1938 and are junior to over 97% of the claimed direct flow rights in the basin. Except for May and June, inflows to the reservoir normally are released to meet the demands of the senior direct flow rights. Historically, the reservoir has filled nearly every year. Storage occasionally occurs in other months during brief storm runoff periods. Water right applications are presently being processed.

PAYMENT RESOURCES

Funding for this project is expected from three sources described as follows:

- A loan and grant through the Small Reclamation Projects Act (P.L. 84-984) administered by the U.S. Bureau of Reclamation. One of the requirements of this program is that irrigators repay their share of the loan without interest but must pay 100% of their "payment capacity". Analysis by USBR guidelines indicates no "payment capacity". However the irrigators have indicated a "willingness to pay" $5.00/AF which, on a cash flow basis, is available from returns to management, labor and equity. Municipal users must repay their share of the loan with interest. The municipal assessment will be $31/AF. A grant of $775,000 is requested based on recreational use of the reservoir.

- A state grant of $496,000 is requested based on recreational benefits and dam safety benefits to the public.

- An additional $107,975 would be provided by the state through the Water Development Program funded from Coal Severance Tax Bond proceeds. This money would be repaid with interest to the state by the municipal water users.

SUMMARY OF FINANCIAL PROGRAM

Period of Repayment	40 years
Interest Rate	7-1/2%

ANNUAL ASSESSMENT SCHEDULE ($/AF)

	Municipal	Agriculture
P.L. 84-984 Loan & State Bond Repayment	$30.22[1/]	$4.00
O,M&R	1.00	1.00
Existing Debt	-0-[1/]	-0-
Emergency Fund	-0-[2/]	-0-
	$31.22	$5.00

1/ Most existing debt is paid.

2/ An adequate emergency fund is established.

CHAPTER I
GENERAL INFORMATION

INTRODUCTION

This investigation was completed on Middle Creek Dam to determine what measures should be undertaken to make the dam safe. Other problems, not relating to safety, were also addressed as a part of this study. Middle Creek Dam (Hyalite Reservoir) is owned by the State of Montana and administered by the Montana Department of Natural Resources and Conservation (DNRC). It is operated by the Middle Creek Water Users Association (MCWUA).

A Phase 1 investigation completed by the Corps of Engineers revealed that the dam cannot safely pass one-half the probable maximum flood (PMF)(COE, 1980). Field inspection and preliminary hydrologic analyses indicated that the dam does not conform to inspection guidelines (COE, 1975) with respect to discharge and does not have the storage capacities needed to pass the recommended spillway design flood. There is considerable potential for loss of life and destruction of property if the dam should breach by overtopping during a large flood.

The Corps of Engineers made the following recommendations (COE, 1980):

> "A downstream warning system, for use in the event of possible dam overtopping or structural failure, must be developed and implemented immediately. Remove flashboards from the spillway. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

Investigate source of left abutment seepage by the installation of piezometers and study of the data. Sample and test the embankment and foundation soils and conduct stability analyses using piezometric data.

Conduct periodic inspections of the facility at intervals not to exceed 5 years by engineers experienced in dam design and construction."

A subsequent feasibility study was made by HKM Associates under contract with DNRC. The resulting report details an engineering plan and describes the financial arrangements needed to solve the safety concerns and other problems identified in the Phase I report (HKM, 1985). Throughout this report the reader will be referred to four other supporting reports which have been completed as follows:

1. Hydrologic Potential For Hyalite Creek Watershed, HKM Associates, November 1983.

2. Geotechnical Investigation, Middle Creek Dam, HKM Associates, April 1984.

3. Flood Hydrology, Middle Creek Dam, HKM Associates, April 1984.

4. Middle (Hyalite) Creek Dam, Rehabilitation Feasibility Study, HKM Associates, February 1985.

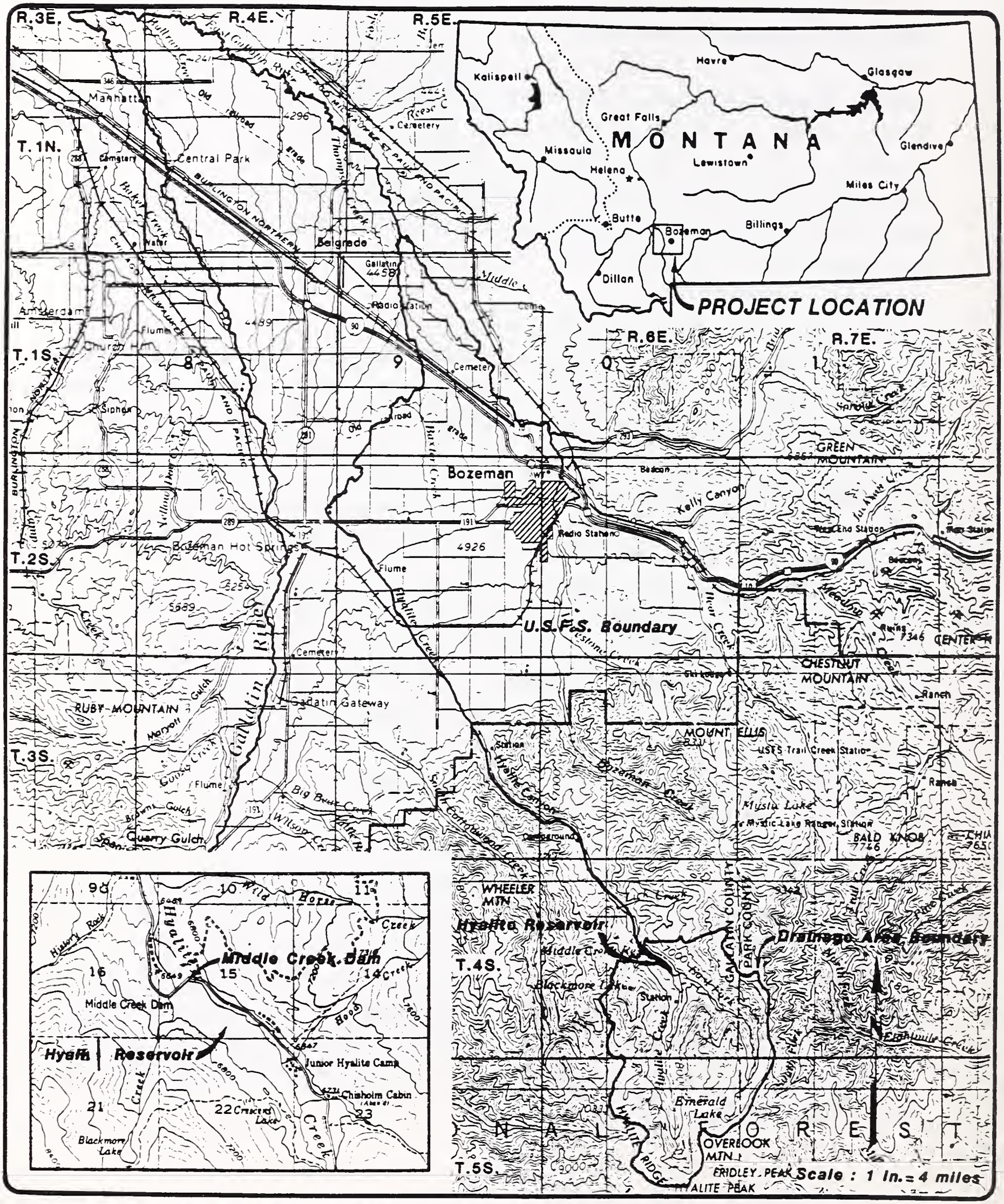
These four reports have been used in preparation of this loan application. The reader should refer to them if additional detail is needed.

DAM LOCATION AND PHYSIOGRAPHY

Middle Creek Dam is located on Hyalite Creek approximately 14 miles south of Bozeman, Montana; slightly inside the northern border of the Gallatin National Forest. (See Figure I.1) The dam and reservoir occupy portions of Sections 15, 22 and 23, T4S, R6E in Gallatin County. The project has an approximate latitude and longitude of 45 degrees, 30 minutes and 111 degrees, respectively.

A 27-square-mile drainage basin feeds the storage project. The basin lies in the Gallatin Range of the Rocky Mountain Physiographic Division (Missouri Basin Inter-Agency Committee, 1971). Elevations within the study basin range from approximately 6,700 feet National Geodetic Vertical Datum (NGVD) at Middle Creek Dam to approximately 10,300 feet NGVD along the Hyalite Ridge which forms the southwestern divide of the contributing watershed. An area-altitude analysis was performed using 15-minute USGS quadrangle maps to characterize the watershed (HKM, April 1984a). The results show that nearly two-thirds of the contributing watershed fall within the 7,000- to 9,000-foot range. Mean basin elevation above the dam is 8,324 feet NGVD. A drainage area summary for the Hyalite Creek Basin is provided in Table A2, Appendix A of the Flood Hydrology Report (HKM, 1984a).

The watershed is nearly rectangular in shape. The East and West Fork drainages of Hyalite Creek have limited flow records above Hyalite Reservoir. Both forks of Hyalite Creek drain in a northerly direction above the gages. The 7.6-square-mile contributory area between the gages and the dam is elongated in the transverse direction. The drainage basin downstream of the dam but upstream of the Ranger Station gage again assumes an elongated shape.



MIDDLE CREEK DAM REHABILITATION

GENERAL LOCATION MAP

8M087.113

SEPTEMBER 1984

FIGURE I.1

HKM ASSOCIATES
ENGINEERS-PLANNERS

The drainages above the dam are characterized by steep, rugged terrain along the divides, and talus slopes from the exposed rock faces to the stream channels. There are a few high-mountain lakes in both drainages, and there are scattered clear-cut zones due to timber harvesting. The terrain, climate and soil conditions play an important role in the basin hydrology. A significant amount of precipitation is either absorbed into the soil to be consumptively used by the vegetative cover, is temporarily lost to the subsurface strata and later shows up as streamflow, or is permanently lost to deep percolation. Overland flow in these mountain drainages is minimal.

Hyalite Creek flows approximately 9 miles through a steep, narrow canyon until leaving the Gallatin Range. Hyalite Creek then flows northwesterly and northerly for about 17 miles before joining the East Gallatin River. The East Gallatin River is a tributary of the Gallatin River which, in turn, is a tributary of the Missouri River. Hyalite Creek is slightly incised in the valley alluvium as it travels from the canyon mouth to the East Gallatin River.

CLIMATE

Reservoir Basin Climate. Climate of the Hyalite watershed can be classified as moist subhumid (Missouri Basin Inter-Agency Committee, 1971). Similar to other subbasins in the Gallatin River Basin, the Hyalite watershed typically receives its least precipitation in the summer months of July and August, and the most precipitation in April through June. September generally initiates an increase in precipitation due to fall rainstorms, with snowfall occurring in subsequent months. The snowfall contributes to winter snowpack accumulation in the upper watershed. Significant snowmelt above Middle Creek Dam

generally does not begin until late April and can last until the early part of July. Storms in the form of rain, snow, or snow-mixed-with-rain contribute to the peak precipitation months in the spring.

The climate of the Hyalite Reservoir Watershed is discussed in detail in Hydrologic Potential For Hyalite Creek Watershed (HKM 1983) and Middle Creek Dam Flood Hydrology (HKM, 1984a).

Agricultural Service Area

Precipitation and temperature patterns of the agricultural service area are recorded by the Bozeman climate station located at Montana State University. The mean annual precipitation (1931-1982) at the MSU station is 18.4 inches. Historic precipitation measurements (1931-1982) for the Bozeman station are provided in Table IV.2. Temperatures in the service area follow a diurnal pattern and exhibit definite daily and seasonal variations. Average temperatures at the Bozeman station vary from 20.8° fahrenheit (°F) in January to 66.7°F in July. Wintertime temperatures are consistently below freezing, with occasional severe cold spells and warm chinooks.

The growing season for alfalfa starts when the spring mean daily temperature reaches 50°F and ends with the first occurrence of a 28°F killing frost. Spring grains have a growing season from 45°F mean daily temperature in the spring until maturity approximately 130 days later.

The last occurrence of 28°F temperatures in the period 1931-1982 varied between April 12 and June 8. The first occurrence of 32°F temperatures during the same period varied from July 2 to October 30. The average growing season during 1931-1982 was 144 days for alfalfa and 131 days for barley.

The most damaging storms are hailstorms which occur most frequently in July and August, and less frequently in June and September. Tornadoes develop very infrequently in the Bozeman area. Severe drought is very uncommon (NOAA, 1974) for the Bozeman area.

of previously constructed projects. Gradually the water users associations assumed responsibility for operation and maintenance, with the MWRB serving in a supervisory capacity.

Changes have continued to take place. When state government was reorganized under a new state constitution in 1971, the MWRB was replaced by the DNRC. The DNRC's Centralized Services Division was originally given the responsibility for accounting and billing for the projects. That duty has now been assumed by the DNRC's Engineering Bureau.

Most projects are administered through water marketing and water purchase contracts with the local water users association. A water <u>marketing</u> contract is a two-party agreement between the DNRC and an association, which states the association's obligation to sell water, collect payments from the users and repay the state's investment. Under most of these contracts there is no provision for the association to own a project when it is paid off. A water <u>purchase</u> contract is a three-party agreement between an individual water user, the association and the DNRC. It sets forth the conditions of water delivery to the water user and the terms of payment for the water. The amount paid is proportionate to the amount of water received, and consists of a principal payment, which is applied toward repayment of the state's investment, and an OM&R payment, which is used by the water users association for operation and maintenance of the project.

On several projects, the state has extended loans to the associations for major repairs. These loans are repaid by renegotiating the original water marketing and water purchase contracts or by entering into a special repayment contract between the association and the DNRC.

Status of the state's investment as of June 30, 1986 is outlined by project in Table II.1.

TABLE II.1

RECOVERY OF STATE INVESTMENT FROM INCEPTION TO JUNE 30, 1986

	Receivables, 6/30/86	Status of State Investment, 6/30/86
Outstanding Investment 6/30/86	Water Purchase Contract	Potential State Revenue Exceeding Investment
129,370.77	2,170.70	131,541.47

The following excerpt was taken directly from Water Resources Survey, Gallatin County (State Engineers Office, 1953):

MIDDLE CREEK STORAGE PROJECT (SWCB)

"In order to supplement the water supply for irrigation in Gallatin Valley the State Water Conservation Board received a loan and grant offer from the Federal Government in 1938 to construct the Middle Creek Storage Project. About the same time the Board filed an appropriation dated July 12, 1938, on all the unappropriated water from Middle Creek (also called Hyalite Creek) and its tributaries. The loan and grant offer required the formation of the Middle Creek Water Users' Association as an agency for the distribution of water, to accumulate funds to amortize the cost of the project, and to execute a Water Marketing Contract with the State Water Conservation Board.

The Middle Creek Water Users' Association was incorporated on January 3, 1939, with a capital stock valued at $10,000 divided into 10,000 shares at $1.00 per share. Water Purchase Contracts in the amount of 8,605[1/] acre feet were secured and approved by the Association on June 9, 1939. The original list was comprised of 108 water purchase contracts with the cost of water established at $1.96 per acre foot. Besides the cost of the water, operation and maintenance charges were set at 26 cents per acre foot.

Bids for construction of the project were received on May 26, 1939, and work was started on the dam July 15, 1939. The dam is located on Middle or Hyalite Creek in Section 15, Township 4 South, Range 6 East, approximately 15 miles south of Bozeman. It is an earth, gravel and rock fill structure, 1,310 feet in length, 110 feet high, and floods an area of 248 acres with a total storage capacity of 8,027[2/] acre feet. Above the reservoir is a 27 square mile drainage area, located in a good snow belt, high on the timbered slopes of the Gallatin Range.

Under the same project a diversion canal from Middle Creek to Cottonwood Creek was constructed to transport water to users along Cottonwood Creek. The Cottonwood diversion canal is 3-1/2 miles long and has a carrying capacity of 77 second feet.

1/ Presently, 7810 acre feet of water storage is contracted.
2/ Based on previous elevation-area-capacity data.

This project was scheduled for completion in 1942 but due to shortages of labor, materials, and increased construction costs during and after World War II, it was not ready for operation until the fall of 1950. The first stored water delivered to water users was the season of 1951.

Supplemental water from the reservoir is supplied to users in the Farmers Canal, Hoy Ditch, Middle Creek Ditch, West Gallatin Canal (Kleinschmidt) and to various private ditches."

Financial Status of MCWUA

Present OM&R assessments (1986) are $0.90/AF. By 1991 (year of first payment) assessments are projected to be $1.00/AF. Final payment on the existing debt will be made in 1995 on the last contract signed as shown in Table IX.5. The principal payment is $1.96/AF on the existing debt.

The financial statements of the MCWUA for the years 1981-1983 are presented on the following pages.

Table II.2

Middle Creek Water Users' Association

FINANCIAL STATEMENT

November 1, 1982 - October 31, 1983

BALANCE: November 1, 1982			$2,068.68
INCOME:			
Receipts 3054-3164			
Principal	$6,977.60		
O & M	7,029.00		
Interest (St. share)	7.84		
" Assoc.	4.05		
City (winter water)	2,594.74		
TOTAL		$16,613.23	
			$18,681.91
DISBURSEMENTS			
Checks #1131-1234			
Mt. Dept. Natural Resources	$6,985.44		
Salary, dam tender	2,587.01		
Secretary	653.10		
Repairs - materials	886.46		
Labor	2,746.00		
Office expense	149.80		
Social Security	215.74		
St. Comp. Ins. Fund	161.56		
Liability Insurance	456.00		
Water Commissioner--Farmers	225.00		
Middle Creek	568.89		
Miscellaneous	81.25		
TOTAL		$15,716.27	$15,716.27
BALANCE			$ 2,965.68
CHECK BOOK & BANK BALANCE			$ 2,965.68
INVESTMENTS			
Insured Money Market Fund #91-916-7		$17,106.37	
C. D. #41054		4,041.61	
TOTAL			$21,147.98
TOTAL AVAILABLE			$24,113.66

Table II.3

MIDDLE CREEK WATER USERS' ASSOCIATION

FINANCIAL STATEMENT
November 1, 1981-October 31, 1982

BALANCE: November 1, 1981		$574.85	574.85
INCOME:			
Receipts # 2940-3053			
Principal	$8,790.60		
O & M	6,248.00		
Misc. (Portion ofCD #47034	3,400.00		
Interest. St.	48.51		
" Assoc.	30.71		
City - Winter Water	1,605.00		
TOTAL		$20,122.82	
			$20,697.67
DISBURSEMENTS			
Checks #1098-1131			
Mt. Dept. Natural Resources	$8,839.11		
Salary, dam tender	2,693.13		
Secretary	653.10		
Repairs- materials	3,506.97		
Labor	947.50		
Equipment purchase	570.00		
Office expenses	180.74		
Social Security	226.77		
St. Comp. Insurance	55.67		
Liability Insurance	466.00		
Water Commission '81 & '82	450.00		
Miscellaneous	40.00		
		$18,628.99	$18,628.99
BALANCE			2,068.68
Checkbook & Bank Balance			2,068.68
INVESTMENTS			
CD #41054 on deposit at 1st Security Bank (interest earned $305.81)		$3,587.77	
CD #47034 mature 10/14/82	$19,157.34		
Deposited in Checking Acct.	3,400.00		
Deposited in Savings Acct #5007178		$15,757.34	
			$19,345.11
TOTAL AVAILABLE			[redacted]

Table II.4

MIDDLE CREEK WATER USERS' ASSOCIATION

FINANCIAL STATEMENT

November 1, 1980-October 31, 1981

BALANCE:	November 1, 1980		#3,738.23	$3,738.23
INCOME:				
Receipts #3838-2939				
Principal			$12,896.80	
O & M			6,248.00	
Misc. (Interest C.D. #34991				
		$1165.77	3,016.82	
				$22,161.62
	TOTAL			$25,899.85
DISBURSEMENTS				
Checks #1098-1131				
Mt. Dept. Natural Resources			$12,896.80	
Salary, dam tender			2,849.83	
Secretary			583.44	
Materials			489.19	
Labor	(Cottonwood Canal)		3,451.80	
Insurance (Liability)			425.00	
Office expenses			135.97	
Investment Bond			3,000.00	
Social Security			209.03	
St. Comp. Insurance			105.17	
Water Commissioner			1,153.77	
Miscellaneous			25.00	
			$25,325.00	$25,325.00
	Balance			574.85
	Checkbook Balance	10/31/81		574.85
INVESTMENTS				
Certificate of Deposit #41054				
on deposit at 1st Security Bank				
earned interest	$184.39	$3,184.89	3,184.89	
Certificate of Deposit #39307				
1st Security		16,824.64	$16,824.64	
			$20,009.53	$20,009.53
	TOTAL AVAILABLE			$20,584.38

CHAPTER III
LANDS

LAND CLASSIFICATION

On June 25, 1985, personnel of the USBR toured the irrigated lands served by Middle Creek and reported the following information:

"The best source of complete reference data available was the USDA published (1931) Soil Survey of the Gallatin Valley Area, Montana. This survey appears to be of high quality in which Bozeman silt loam, Bozeman brown phase, and Huffine silt loam are the major soil series with inclusions of Huffine poorly drained phase and scattered Huffine gravelly soil profiles. Two augered soil borings verified that loam, silt loam to very fine sandy loam were dominant soil textures with depths to underlying gravel and cobble ranging from 6 to 60 inches with an average depth of 12-18 inches throughout the entire irrigated valley.

Some lands do have surface cobble and stone features which would be a limitation for row crops, but since due to the climate only alfalfa, domestic grasses and small grains are raised, this is not a major factor.

Most lands have been gravity irrigated for 40 to over 100 years adjacent to Middle Creek or small contributing drainageways. Topography is nearly level to slightly undulating with gradient of 1 to 2 percent. These relatively high intermountain lands are naturally very fertile, moderately high in organic matter and nonsaline or alkaline since the parent material is basically fine grained lake-bottom sediments from a former lake bed which existed in late Tertiary period.

Low positioned elongated fields are presently poorly drained, but fairly well adapted for pasture grasses such as timothy, redtop and Kentucky blue grass. If provided with shallow drains, these lands would have a beneficial watertable but deep drains could contribute to a droughty soil condition since the coarse sand, gravel and cobble is relatively near the surface. No subsurface drains were observed during the trip through the irrigated lands.

Conclusions

Most irrigated lands observed on this trip have been very successfully irrigated for a long time with moderate to high yields of climatically adapted crops with a growing season of 110-120 days and 16-20 inches of annual precipitation.

Less than 20 percent of the total lands have major land deficiencies which includes the poorly drained or very gravelly Huffine soils.

No further investigation is necessary to verify successful irrigation in this portion of the Gallatin Valley Area."

Descriptions of the five major soils described are found in Exhibit G.

HAZARDOUS SOIL CHARACTERISTICS AND TOXIC RETURN FLOWS

Available data was reviewed to determine if any toxic or hazard soil characteristics exist in the project area. Contacts were made with Montana State University (MSU, 1986), the City of Bozeman (Bozeman, 1987), the U.S. Forest Service (USFS, 1987), the Soil Conservation Service (SCS, 1986), and the Montana Department of Health and Environmental Sciences (MDHES, 1987). Pertinent publications are available from the U.S. Geological Survey (Hackett, et.al., 1960) and the Blue Ribbons of the Big Sky Country Areawide Planning Organization (Blue Ribbons, 1979).

One component of the Blue Ribbons Report (Blue Ribbons, 1979) was an agricultural study. The agricultural study "was intended to identify and where possible, quantify pollutant loads from agricultural lands in the Gallatin and Madison drainages". Sampling for flow volume, dissolved solids, sediment, nutrients, microbiological contaminants, and trace elements took place between May 1976 and July 1977. The only negative finding with respect to Hyalite Creek was that it can be completely dewatered in spots during the irrigation season.

Trace element testing was performed for lead, iron, zinc, copper, mercury, arsenic and fluoride. This did not include all the trace elements of concern to the USBR, and it was agreed that an additional water sample would be taken from Hyalite Creek and tested for the 32 constituents of interest to the USBR (Lucero, 1987).

Background Information

The original plan assumed that flow in Hyalite Creek near its mouth at the time of the proposed February 19, 1987 sampling, would represent the base flow of the stream and include ground water return flows from lands irrigated by water from Hyalite

Creek. A series of streamflow measurements by Montana Department of Natural Resources and Conservation (DNRC) personnel February 18, 1987, indicated that Hyalite Creek was a losing stream and that there was no flow in the Creek at the proposed water quality sampling site. The sampling and analysis of water in Hyalite Creek for toxic return flows was eliminated from further consideration. Table III.1 presents the results of the February 18, 1987 DNRC Hyalite Creek Streamflow measurements.

TABLE III.1

LOCATION AND RESULTS OF STREAM FLOW MEASUREMENT
MADE ON HYALITE CREEK, FEBRUARY 18, 1987 (Clark, 1987a)

LOCATION	MEASURED FLOW (CFS)	REMARKS
NE1/4 SW1/4 Sec. 14, T.3S., R.5E.	13	---
SW1/4 NE1/4 Sec. 29, T.2S., R.5E.	12.6	---
NE1/4 NE1/4 Sec. 13, T.2S., R.5E	10.3	---
NE1/4 NW1/4 Sec. 30, T.1S., R.5E.	---	Trace flow interlayered in ice, couldn't measure
NW1/4 NW1/4 Sec. 20, T.1S., R.5E.	---	Trace flow interlayered in ice, couldn't measure
SW1/4 NE1/4 Sec. 17, T.1S., R.5E.	0	Stream froze solid
NE1/4 NE/14 Sec. 8, T.1S., R.5E	0	Stream froze solid

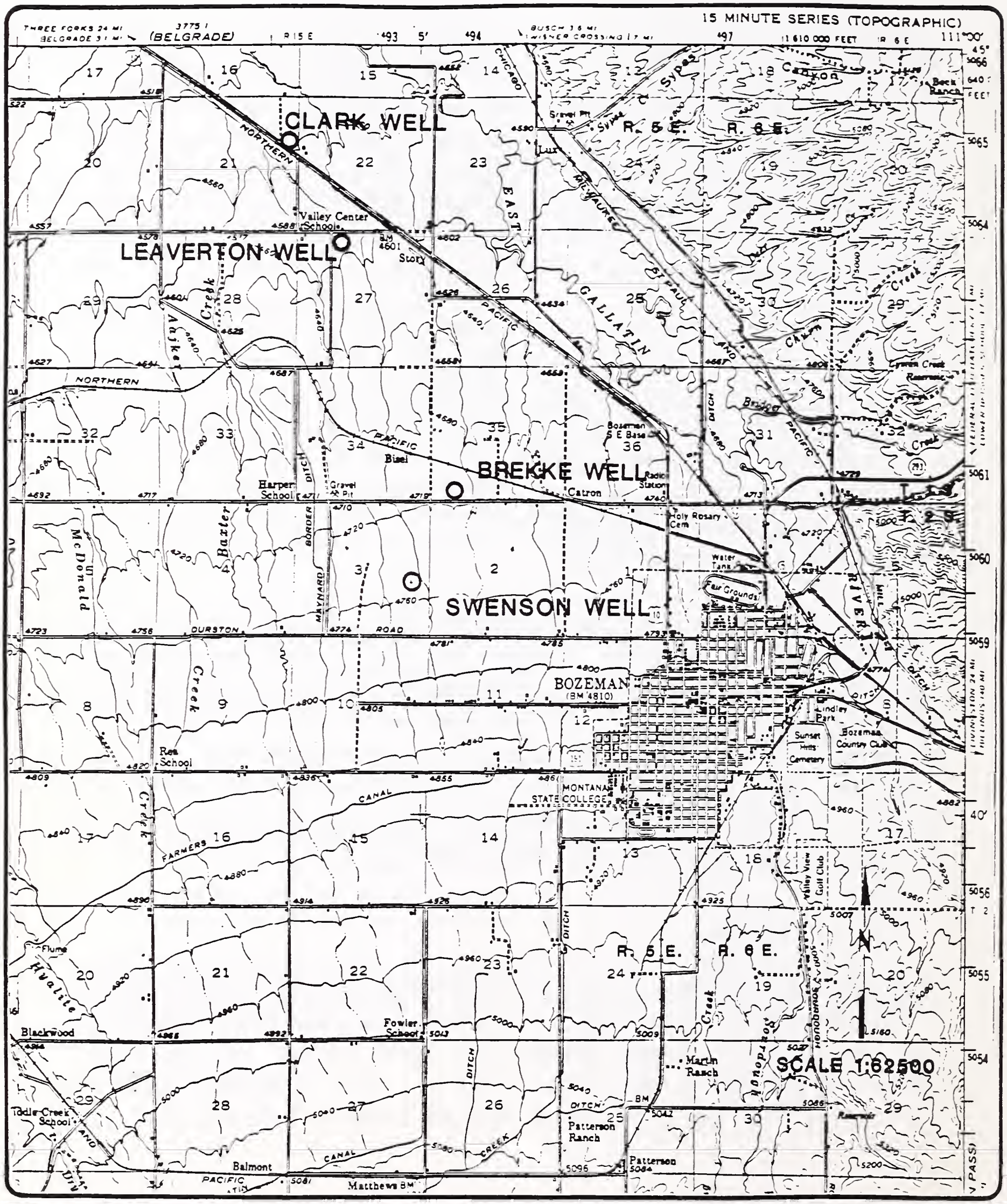
Due to the lack of flow in Hyalite Creek, it was deemed necessary to pursue a ground water sampling program to investigate toxic return flows via ground water for the Middle Creek Dam Project. Due to a combination of budget, institutional and time constraints, it was concluded that the most effective means of performing the toxic return flows investigation was to locate and then sample four suitable existing wells.

A review of existing information indicated that ground water in shallow aquifers of the Bozeman alluvial fan would be most likely to show the effects of irrigation from water from Hyalite Creek. A screening process involving the utilization of existing published hydrogeologic data and water well drillers logs on file with the DNRC and Montana Bureau of Mines and Geology (MBMG) was used to select the four wells to be sampled in this investigation.

An area at the northern extremity of the Bozeman fan was selected to establish a transect of wells that would reflect the full effect of irrigation on ground water quality in the alluvial fan deposits. Logs of USGS test holes (Exhibit H-1) were used to assist in the screening of 82 water wells in the desired area to select four suitable wells for sampling. Figure III.1 shows the location of the wells selected to be sampled in the toxic return flows investigation.

Geologic Setting

The Gallatin Valley is near the southern border of the northern Rocky Mountain physiographic province. The Gallatin Valley is an intermontane basin bounded by the Bridger and Gallatin Mountain Ranges on the east and south, the Horseshoe Hills on the north and the topographic divide between the Gallatin and



WELL LOCATION MAP, TOXIC RETURN FLOWS INVESTIGATION, MIDDLE CREEK DAM PROJECT, GALLATIN COUNTY, MONTANA

FIGURE III.1

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8M087.121 | MAR. 1987

Madison Rivers on the west. The Gallatin Valley is part of the Three Forks structural basin which includes the Madison Valley and the lower Jefferson River Valley (Hackett, 1960).

Sedimentary rocks ranging in age from Precambrian to recent crop out in the Gallatin Valley and on the flanks of the surrounding mountains. Precambrian metamorphic and sedimentary rocks are the oldest rocks exposed on the flanks of the Gallatin Valley and occur at depth in the valley. The metamorphics are principally gneiss, although schist, quartzite and marble are also present. The Precambrian sedimentary rocks consist mostly of arkosic sandstone and conglomerate, graywacke conglomerate, and slate (Hackett, 1960).

Rocks of Cambrian, Devonian, Mississippian, Pennsylvanian, and possibly Permian age are present in the Gallatin Valley and vicinity. These Paleozoic rocks generally consist of quartzite, sandstone, limestone, and shales, and crop out along the flanks of the Horseshoe Hills and the Gallatin and Bridger Ranges. They also locally underlie Tertiary and Quaternary deposits in the valley (Hackett, 1960).

Mesozoic rocks crop out along the northwest margin of the Dry Creek area and east and southeast of the Fort Ellis area on the west flank of the Bridger Range. These rocks generally consist of sandstones, siltstone, shales, limestone and some conglomerate (Hackett, 1960).

Cenezoic rocks constitute the valley fill and are of primary interest with respect to the development and utilization of ground water in the Valley. The Tertiary strata where exposed along the margins of the Gallatin Valley are mostly moderately well cemented fanglomerate, consisting of poorly sorted, locally derived rock fragments in a matrix of clay or

calcareous silt and sand. Toward the center of the valley the Tertiary strata are finer grained and consist principally of tuffaceous siltstone and fine-grained tuffaceous sandstone, which is in places interbedded with marl, pure ash, crossbedded sandstone, and conglomerate. The estimated maximum thickness of the Tertiary strata in the Gallatin Valley is at least 4000 feet (Hackett, 1960).

Unconsolidated alluvium associated with recent (Quaternary) alluvial-fan and stream channel deposits are of primary interest with respect to ground water development in the Valley. The fans are composed of a wide mixture of materials ranging from coarse to fine-grained sediments of locally derived rock up to 200 feet thick. The alluvium on the valley floor and adjacent to principal drainages, generally consists of cobbles and gravel intermixed with sand, clay and silt and is known to be more than 800 feet thick at some locations in the Gallatin Valley.

Hydrogeologic Setting

The Gallatin Valley contains three aquifer systems of interest with respect to ground water. These include the sedimentary, and metamorphic rocks of Precambrian through Mesozoic age that outcrop in the mountain ranges fringing the valley, the Tertiary strata and Quaternary sediments consisting of alluvial fan and valley floor stream laid deposits.

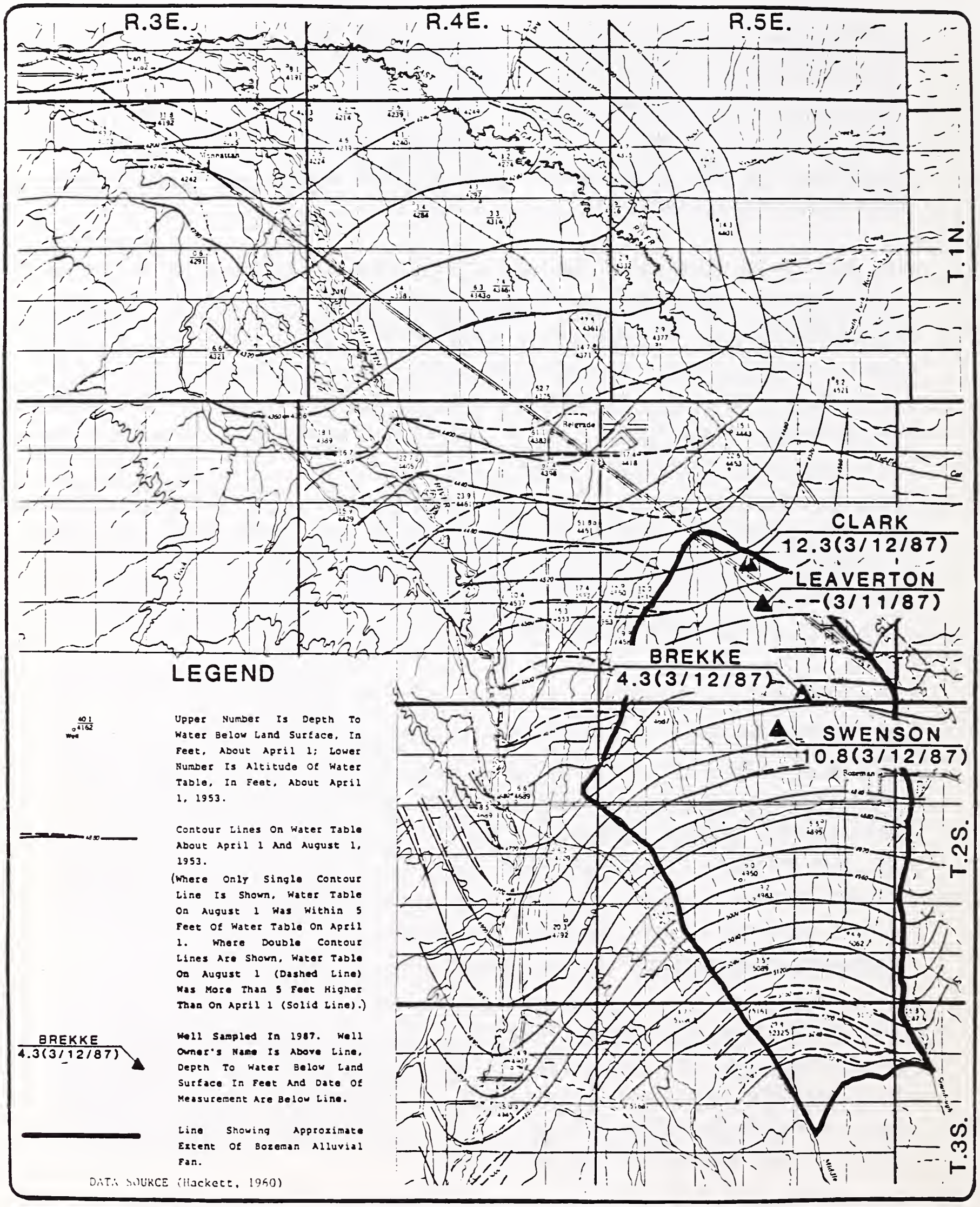
The sediments composing the alluvial fan designated the Bozeman fan by the USGS, are of primary interest with respect to the toxic return flows investigation. These deposits thin from nearly 200 feet near the head of the fan to a hundred feet or less near its toe where it grades into, or interfingers with, the alluvium of the Gallatin and East Gallatin Rivers. The fan

is bounded on the southwest by Goochs Ridge and on the east by Bozeman Creek. The fan merges with the floor of the Gallatin Valley on its northwest margin and with the flood plain of the East Gallatin River on its northeast margin. Aquifers of the Bozeman fan are extensively used in the valley as a source of domestic and stockwater.

Ground water generally occurs under water table conditions in the Bozeman fan and moves south to northwest. The depth of ground water in the fan is variable and ranged from 4.3 to 12.3 feet below land surface in the wells sampled for this investigation. The transmissivity of the alluvial-fan deposits as determined at six sites by the USGS ranged from 3476 to 8690 ft^2/day and averaged about 6417 ft^2/day (Hackett, 1960). Figure III.2 presents a contour map of the water table in the Gallatin Valley, including the Bozeman fan, that was prepared for USGS Water Supply Paper 1482 (Hackett, 1960). The general outline of the Bozeman fan and the location of the wells used for this investigation are also shown in Figure III.2.

Streamflow, irrigation water, and precipitation are the principal sources of recharge to aquifers in the Bozeman fan. The USGS reported that Bozeman and Hyalite Creeks, near where they enter the valley, are sources of recharge, particularly during the months of high streamflow and low ground water level in the spring. Seepage from the numerous irrigation ditches crossing the surface of the fan, and infiltrating irrigation water applied to the fields, are generally the main sources of recharge during most of the summer (Hackett, 1960).

The USGS reported that precipitation is somewhat greater in this part of the Gallatin Valley than elsewhere. Generally much of the winter precipitation is stored as snow; snowmelt and relatively high rainfall in the spring also produces appreciable recharge (Hackett, 1960).



LEGEND

401 / 4162 Well — Upper Number Is Depth To Water Below Land Surface, In Feet, About April 1; Lower Number Is Altitude Of Water Table, In Feet, About April 1, 1953.

4450 — Contour Lines On Water Table About April 1 And August 1, 1953. (Where Only Single Contour Line Is Shown, Water Table On August 1 Was Within 5 Feet Of Water Table On April 1. Where Double Contour Lines Are Shown, Water Table On August 1 (Dashed Line) Was More Than 5 Feet Higher Than On April 1 (Solid Line).)

BREKKE 4.3(3/12/87) — Well Sampled In 1987. Well Owner's Name Is Above Line, Depth To Water Below Land Surface In Feet And Date Of Measurement Are Below Line.

Line Showing Approximate Extent Of Bozeman Alluvial Fan.

DATA SOURCE (Hackett, 1960)

Map Showing Water Levels in Wells Sampled March 12, 1987 in Relation To The Contour of the Water Table in the Gallatin Valley as Mapped April 1 & August 1, 1953

FIGURE III.2

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The USGS reported that, discharge of ground water from the Bozeman fan is by effluent seepage to streams, by underflow to adjacent areas down valley, and by evapotranspiration. Hyalite and Bozeman Creeks, the only streams that completely cross the Bozeman fan were reported in 1960 to be effluent in the lower parts of their courses across the fan. Several small streams rise about 3 miles north of the head of the fan and drain northward into either Hyalite Creek or the East Gallatin River. During the irrigation season, most of the water in the streams draining the Bozeman fan is diverted for irrigation. Evapotranspiration is greatest along the streams and drains on the fan. Underflow from the Bozeman fan enters the alluvium underlying the Belgrade plain and the flood plain of the East Gallatin River (Hackett, 1960).

Data from samples collected by the USGS between 1951 and 1953, and reported in Water Supply Paper 1482, indicated ground water in the Bozeman fan to be of relatively high quality with conductivity and total dissolved solids concentrations ranging between 234 and 552 micromhos per centimeter at 25° Centigrade and 140 to 343 mg/l respectively. Calcium and magnesium were generally the dominant ions with concentrations ranging from 28 to 72 mg/l and 5.4 to 22 mg/l respectively. Sulfate concentrations ranged from 1 to 27 mg/l and nitrate concentrations ranged from 0.05 to 0.61 mg/l as nitrogen. Reported Boron concentrations ranged from 0.01 to 0.09 mg/l. No data was available on the concentrations of trace metals as these constituents were not included in the analyses performed by the USGS for Water Supply Paper 1482 (Hackett, 1960).

FIELD INVESTIGATIONS

The primary objective of the field investigations was to sample selected wells to define the quality of the ground water in the Bozeman fan for the toxic return flows investigation. The

background and process for selecting the four wells that were sampled has been previously described.

All four of the wells are presently used for domestic purposes including lawn and garden irrigation. The wells are the primary source of water for single family residences at all four locations. Other than residential and farming, there was no apparent land use in the vicinity of the four wells that could affect the quality of ground water from the wells when they were sampled March 11 and 12, 1987. Table III.2 summarizes available information on the four wells used in this investigation. Exhibits H-2.1, H-3.1, H-4.1 and H-5.1 present copies of the original drillers logs for the four wells.

The wells were visited and sampled March 11 and 12, 1987. When possible, static water levels were measured in each well prior to sampling. Each well was then purged during which water temperature, conductivity and pH were periodically monitored to insure that a representative sample was obtained from the aquifer. All samples were collected, preserved and delivered to Energy Laboratories, Inc. in Billings, Montana on March 13, 1987. Exhibits H-2.2, H-3.2, H-4.2 and H-5.2 present a summary of field data acquired during well purging and sampling operations on the wells.

Energy Laboratories analyzed the four samples for the 32 constituents as identified by USBR (USBR, 1986). Sample preservation and analyses were performed according to Standard Methods for Chemical Analysis of Water and Wastewater and the U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes (American Public Health Association, 1985), (EPA, 1979). The laboratory performed and reported Quality Assurance practices on the four samples as stipulated by USBR (Lucero, 1987). Exhibit H-6.1 presents Energy Labs Quality Assurance Manual and Exhibit H-6.2 presents the results of the Quality Assurance Program performed for this investigation.

TABLE III.2

SUMMARY OF DATA FOR WELLS USED IN TOXIC RETURN FLOWS INVESTIGATION

MIDDLE CREEK DAM PROJECT, GALLATIN COUNTY, MONTANA

Location	Owner	Well Total Depth (Feet Below Land Surface)	Date Completed	Major Aquifer	Water Bearing Material	Static Water Level (Feet Below Land Surface)	Date Measured	Inside Casing Diameter (inches)	Completion Interval (Feet Below Land Surface)	Use	Yield[A]/ (gpm)
SE¼NE¼ Sec. 21, T.1S., R.5E.	T. Clark	64	3/2/83	Bozeman Fan	Gravel	12.3	3/12/87	6.0	64[B]/	Domestic	30
NW¼NE¼NE¼ Sec. 27, T.1S., R.5E.	M. Leaverton	41	6/18/73	Bozeman Fan	Sand & Gravel	12.0	6/18/73[C]/	6.0	41[B]/	Domestic	30
E½SW¼SW¼ Sec. 35, T.1S., R.5E.	L.J. Brekke	46	9/-/81	Bozeman Fan	Sand & Gravel	4.3	3/12/87	6.0	46[B]/	Domestic	40
E½SE¼ Sec. 3, T.2S., R.5E.	R.J. Swenson	52	9/15/73	Bozeman Fan	Sand & Gravel	10.8	3/12/87	6.0	52[B]/	Domestic	25

A/ Yield reported on drillers log.

B/ Open end completion

C/ Water level measured at time well was drilled and completed. Static water level was not measured 3/11/87 when well was sampled.

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Results

Data from the samples collected March 11 and 12, 1987 indicated water in the aquifers of the Bozeman fan in which the four sampled wells are completed to be of relatively high quality. Field conductivity values for water from the four wells ranged from 460 to 560 micromhos per centimeter at 25° Centigrade. Calcium appeared to be the dominant ion with concentrations ranging between 68 and 80 mg/l. Magnesium and sulfate were present in lesser concentrations ranging from 14 to 20 mg/l and 10 to 25 mg/l respectively. Nitrate plus nitrite concentrations reported as nitrogen ranged from 0.59 to 3.0 mg/l. Boron concentrations from all four samples were reported as being less than 0.10 mg/l. Concentrations of metals were generally below detection limits in all of the samples except antimony and selenium. Antimony was present in one sample (Clark Well) at a concentration of 0.01 mg/l. Concentrations of selenium ranged from 0.002 to 0.008 mg/l for the four samples. Exhibits H-2.3, H-3.3, H-4.3 and H-5.3 contain the results of the laboratory analyses of the samples from each of the four wells.

Data from the four analyses indicate that ground water sampled in this investigation generally is suitable for use as a source for drinking water and irrigation. All analyzed constituents are within the limits of Federal Primary and Secondary Drinking Water Regulations. Selenium was detected in all four wells, but at concentrations less than the Drinking Water Maximum Concentration Level (MCL) of 0.01 mg/l. Available data indicates that toxic elements are not a problem in the ground water sampled in this investigation. Table III.3 presents a comparison between Federal Drinking Water Regulations, Irrigation Quality Criteria and the constituents as determined in this investigation.

TABLE III.3
COMPARISON OF RESULTS OF LABORATORY ANALYSES OE GROUND WATER SAMPLES TAKEN
MARCH 11 and 12, 1987, TO ORINKING WATER STANOARDS ANO IRRIGATION QUALITY CRITERIA

Constituent	Units	National Primary Orinking Water Standards[A]/	National Secondary Orinking Water Regulations[B]/	Irrigation Water[C]/	Clark Well	Leaverton Well	Brekke Well	Swenson Well
Arsenic	mg/l	0.05	---	0.10	<0.005	<0.005	<0.005	<0.005
Barium	mg/l	1.0	---	---	<0.10	<0.10	<0.10	<0.10
Beryllium	mg/l	---	---	0.10	<0.005	<0.005	<0.005	<0.005
Boron	mg/l	---	---	0.75	<0.10	<0.10	<0.10	<0.10
Cadmium	mg/l	0.01	---	0.01	<0.001	<0.001	<0.001	<0.001
Chloride	mg/l	---	250	---	8.0	4.0	5.0	3.0
Chromium	mg/l	0.05	---	0.1	<0.02	<0.02	<0.02	<0.02
Copper	mg/l	---	1.0	0.2	<0.01	<0.01	<0.01	<0.01
Total Dissolved Solids	mg/l	---	500	---	---	---	---	---
Fluoride	mg/l	1.4-2.4[D]/	---	1.0	0.15	0.15	<0.10	0.14
Iron	mg/l	---	0.3	5.0	<0.05	<0.05	<0.05	<0.05
Lead	mg/l	0.05	---	5.0	<0.02	<0.02	<0.02	<0.02
Manganese	mg/l	---	0.05	0.2	<0.02	<0.02	<0.02	<0.02
Mercury	mg/l	0.002	---	---	<0.001	<0.001	<0.001	<0.001
Nickel	mg/l	---	---	0.2	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/l	10.0	---	---	1.8[E]/	3.0[E]/	1.3[E]/	0.59[E]/
pH	Standard Units	---	6.5-8.5	---	7.5	7.6	7.5	7.6
Selenium	mg/l	0.01	---	0.02	0.007	0.008	0.003	0.002
Silver	mg/l	0.05	---	---	<0.005	<0.005	<0.005	<0.005
Sulfate	mg/l	---	250	---	25	16	10	11
Zinc	mg/l	---	5.0	2.0	0.02	0.04	0.02	0.02

A/ (Culp, 1986)
B/ (AWWA, 1979)
C/ (USBR, 1986)
D/ Temperature related standards; minimum 1.4 mg/l when annual average maximum temperature exceeds 26.3°C.
E/ Analyzed and reported as nitrate plus nitrite as N.

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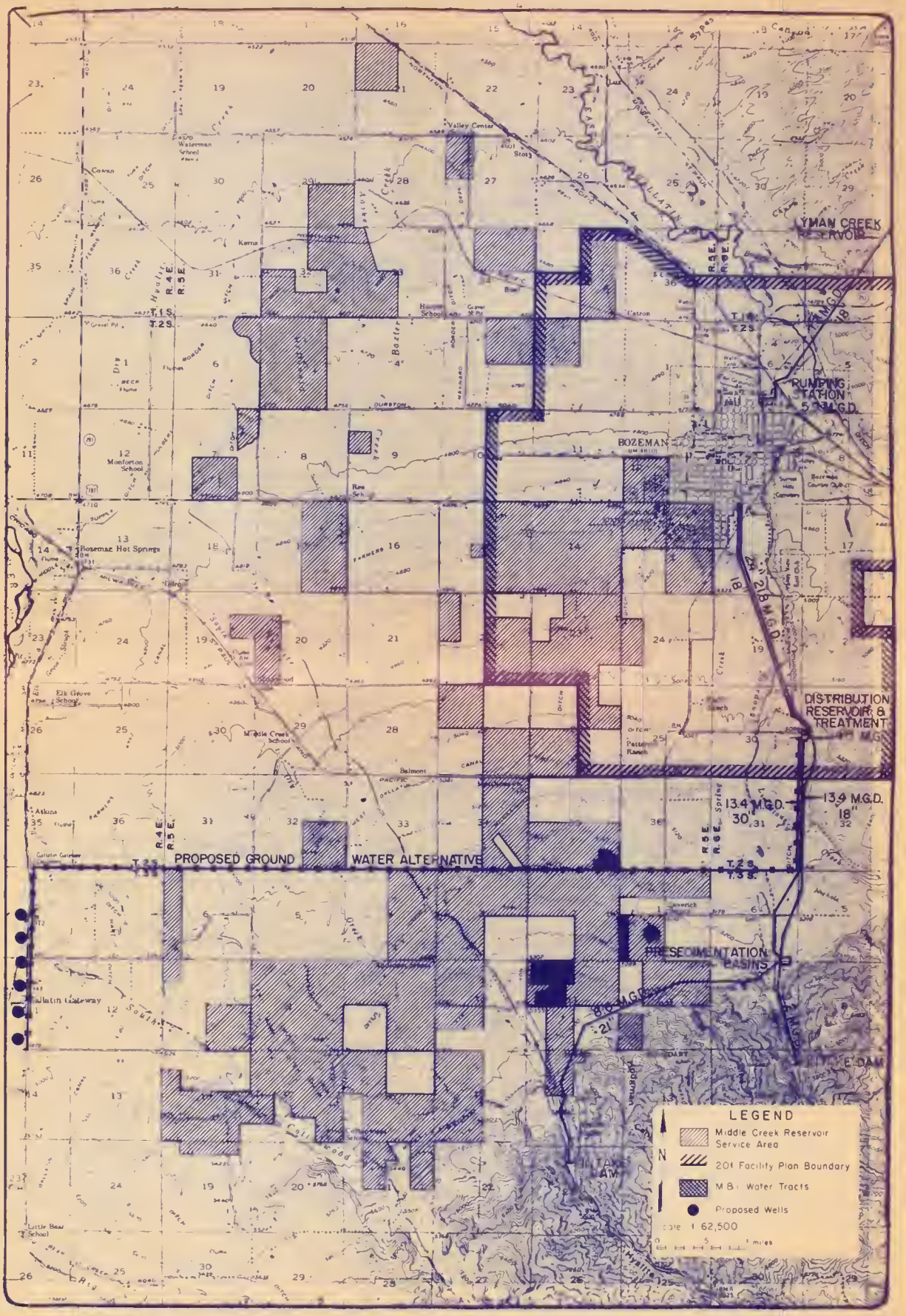
SERVICE AREA

Water is delivered from Hyalite Reservoir (Middle Creek Dam) as a supplemental supply for commercial irrigation, for the municipal (M & I) needs of the City of Bozeman and to small agricultural tracts. Storage water is not tied to a specific place of use as are direct flow rights. For this reason it is difficult to determine a service area as the area is constantly changing. The present service area as shown in Figure III.3 was determined by matching land ownership to contract holders and assuming that storage water would be applied somewhere within this ownership. The service area was determined to be 14,912 acres in size by this method.

As identified in Chapter VIII, Project Evaluation, approximately 60% of a typical farm is irrigated with the rest being dry land farmed or dedicated to homesteads, roads, etc. Assuming this relationship to be applicable to the entire service area 8,950 acres would be irrigated by both direct flow and storage rights.

As shown in Chapter IX, Financial Program, additional storage water not needed for M & I purposes will be made available on a year to year basis for agricultural use. Existing contract holders should be given first priority for contracting this water. However, it is likely that other users outside the present service area would also purchase short-term contracts. As identified in Table III.4, acreage irrigated within the Middle Creek drainage is estimated to be 24,819 acres. Thus, there exists potential for supplemental irrigation water contracts. Only those irrigators with the earliest rights would not need additional late season water supplies.



MIDDLE CREEK DAM REHABILITATION

MIDDLE CREEK RESERVOIR SERVICE AREA

FIGURE III.3

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SEPTEMBER 1984

TABLE III.4
Acreage Served by Hyalite Creek
Direct Flow and Storage

Reach River Mile Index	Description	Acreage Group #	Acreage Served By Direct Flow Acres	Service Area Middle Creek Storage Acres	Storage Contracts Ownership Identified Acre-Feet	Storage Contracts Allocation of Unidentified Owners Acre-Feet	Storage Contracts Total Acre-Feet
28.9	Middle Creek Dam						
20.5	City of Bozeman				2,805	0	2,805
	Right Bank Diversions above Hoy Ditch	7	1,383		715		
19.5	Hoy Ditch	6	1,762		485		
17.0	Middle Creek Ditch	5	5,077		1,050		
20.5	Cottonwood Canal + other East Bank diversions	4	2,022		1,445		
			10,244	11,328	3,695	185	3,880
	Diversions, private between Middle Creek Dam and Farmers Canal	3	1,019		50		
12.6	Farmers Canal	2	12,677		898		
			13,696	3,437	948	52	1,000
	Below Farmers Canal Diversion	1	879	147	120	5	125
	GRAND TOTALS		24,819	14,912			7,810

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It should be noted that the area identified for water right claims by DNRC is substantially larger than the service area identified in this study. This is justified because of the dynamic nature of the delivery of the water. The water rights map should not be compared to the service area map as they serve two entirely different purposes.

In summary, the service area is dynamic but encompasses less than 15,000 acres, of which storage water is delivered to 8,950 acres. There are approximately 10,000 acres of land outside the service area that could receive supplemental storage water from Hyalite Reservoir. New delivery facilities may be required to deliver this water to the Bozeman Creek Area.

CROPPING PATTERNS AND YIELDS

Since production records are not kept specific to the irrigated acreage of the Middle Creek Water Users Association, it is difficult to develop cropping patterns and yields information. Thus, Gallatin County statistics as developed by the Montana Crop and Livestock Reporting Service, (Montana Crop and Livestock Reporting Service, 1983) are adopted. These values should adequately represent the area irrigated and are summarized in Table VIII.1 (See Chapter VIII). Yields are representative of the increased water supply made available by this project.

LAND OWNERSHIP

Two types of land, which are serviced by irrigation water, must bear interest under a Small Reclamation Project Act loan. Those lands that exceed 320 acres in size under ownership of a family unit are called "excess" lands. The excess allocation

of the loan must be repaid with interest. The second type of land which bears interest is small agricultural tracts and suburban lands.

Most of the lands utilizing storage water for supplemental irrigation are held in private ownership. Approximately 600 acres of the lands are state owned in the name of Montana State University. It is estimated that 20 acres are held by Gallatin County. All of these lands are supporting commercial agriculture at this time. Analysis of land ownership maps would indicate that 465 acres of excess lands are held within the service area at this time.

M & I USE

In December of 1984, 2,805 AF of water was held in the name of the City of Bozeman. This portion of Hyalite Reservoir storage is considered M & I water. The 2,805 AF does not include 50 AF of storage right attached to the pending Litchenburg Land and Cattle water right transfer to the City of Bozeman. Should the city successfully complete this transfer, the total storage would increase to 2,855 AF.

Since the irrigation allocation of land repayment does not bear interest under the Small Reclamation Projects Act, it is important to distinguish between commercial farm operations and small agricultural tracts and suburban lands.

The criteria to be followed by the applicant in defining a commercial farm operation is based on a 2-acre minimum limit on tract size and a gross annual sales value approach for tracts between 2 and 10 acres. Water provided to owners of small tracts between 2 and 10 acres that would produce less than $5,000 of gross annual sales of agricultural commodities must be treated as M&I service.

To determine minimum tract size, alfalfa is considered the highest value crop, producing a gross of $227.50/acre (see Chapter VIII, Project Evaluation). Thus, 10 acres would gross $2,275.00 which is less than the $5,000 limit. All tract sizes less than 10 acres which receive storage water would bear interest in loan repayment.

Tracts of 10 acres or less were estimated by superimposing the service area map over large scale aerial photos. Homes and yard boundaries could be identified on these maps in areas obviously subdivided. In this manner, 177 acres were identified with a tract size ranging from 5.5 to 1.95 acres. Storage contracts relating to these lands total 330 AF but include areas which have not been developed into home sites. It is estimated that 1 AF/acre or 177 AF are actually released from storage for these tracts. It should be noted that this calculation was made for purposes of the financial analysis. Actual acreage falling into the "small tract" category will be calculated each year and appropriate adjustments made in the loan repayment.

In summary, 2,980 AF are presently eligible for M & I allocation. This value is rounded to 3,000 AF and projected to 1991 demand in the cost allocation in Chapter IX, Financial Program. The additional 2334 AF of storage water would be used primarily by agriculture on a temporary basis and held for the city as needed. At or before the expiration of the 40-year loan term, all of this water would likely be committed to M & I use.

CHAPTER IV
WATER

WATER REQUIREMENTS

Monthly farm delivery requirements and diversion requirements were developed using both records and calculated consumptive use requirements. Consumptive use and effective precipitation were calculated using the Blaney-Criddle Method, SCS TR-21 version (SCS, 1970), for alfalfa and barley using Bozeman, Montana climatic data. Precipitation for Bozeman is shown in Table IV.1. Summary tables for consumptive use are provided in Tables IV.2 and IV.3. Detailed printouts of consumptive use can be referenced in the files.

Net irrigation requirements were calculated by subtracting effective rainfall from consumptive use. See Tables IV.4 and IV.5 for effective precipitation for barley and alfalfa respectively. A weighted net irrigation requirement was obtained using a cropping pattern of 62.5% alfalfa and 37.5% barley (see Table IV.6).

The following paragraphs, as paraphrased from TR-21 (SCS, 1970), summarize the Blaney-Criddle Technique. This process has been computerized by HKM Associates for ease of calculations.

Early in the 1900's researchers found that the amount of water consumptively used by vegetation during their normal growing season was closely related to mean monthly temperatures and daylight hours. Mr. Harry Blaney and Mr. Wayne Criddle developed equations that could be used to transpose the consumptive use data for a given area to other areas for which

Table IV.1

Monthly Precipitation (Historic)

MONTHLY PRECIPITATION (HISTORIC)

FILE -- BOZPREC1
SITE -- BOZEMAN
UNIT -- INCHES
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE 10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	1.10	1.13	1.37	1.21	2.23	1.50	1.46	.37	2.13	.81	1.19	.79	15.29
1932	1.02	.31	2.25	2.55	.69	3.29	1.55	1.54	.21	2.23	1.13	.56	17.34
1933	.77	.66	.36	1.37	2.56	1.13	.40	3.48	1.37	1.78	.34	.57	15.99
1934	.47	.71	1.33	.19	.88	2.35	.40	.07	1.06	1.47	.32	1.29	10.54
1935	.75	.29	3.24	1.92	2.35	1.76	.77	.70	.15	2.35	.67	.51	15.46
1936	1.19	1.25	.67	.93	1.31	2.13	.09	1.43	1.04	.74	.66	1.29	12.78
1937	1.64	1.15	1.27	2.42	.82	3.90	2.16	.20	2.33	.51	.67	.92	17.99
1938	.38	.44	3.23	1.55	5.63	1.82	1.20	.83	.09	3.10	1.89	.14	20.34
1939	.74	.52	1.02	.99	1.31	3.71	.69	.94	1.29	1.17	.05	1.00	14.03
1940	1.48	1.22	1.28	3.33	1.38	2.99	.61	.45	2.48	1.05	1.25	1.11	18.63
1941	.20	.44	.78	3.50	1.45	3.17	1.26	1.80	4.60	1.17	2.74	1.76	22.86
1942	2.15	1.71	1.48	.79	2.44	2.68	.47	.53	1.54	1.22	1.78	.45	17.24
1943	.88	.32	1.07	3.07	2.10	2.50	1.90	1.24	.91	1.95	.74	.59	17.27
1944	.12	.73	.96	.60	3.00	7.93	1.70	1.42	2.13	.97	.73	.53	20.92
1945	.36	.47	1.15	1.15	3.67	4.10	.76	1.73	1.34	1.15	1.18	1.97	19.53
1946	1.26	1.13	2.36	1.43	3.03	1.33	1.47	.76	1.97	2.35	.85	.59	18.58
1947	.83	.44	3.02	1.38	1.05	6.78	.37	.80	4.58	.69	3.25	1.35	24.53
1948	1.11	.65	.89	2.04	2.37	4.87	1.58	1.91	.60	.52	1.53	1.43	19.50
1949	1.89	.86	1.07	2.06	1.92	3.73	.51	.55	2.21	1.21	.51	.59	17.11
1950	.74	.75	2.00	.99	2.07	2.16	2.74	1.86	1.99	.87	1.10	.92	18.18
1951	.46	.49	1.75	1.84	1.52	1.61	.87	2.36	2.23	4.46	.81	1.80	20.20
1952	1.24	1.19	1.59	1.99	6.63	2.02	1.28	1.16	.56	.21	1.29	.41	19.56
1953	.65	1.05	1.04	2.05	3.23	3.13	.63	.42	1.00	1.39	1.13	.58	16.40
1954	1.10	.13	1.19	.44	1.70	3.70	.66	1.32	1.21	.88	.07	.23	12.68
1955	.54	1.00	1.33	3.51	2.70	2.23	1.55	.12	1.11	2.04	.78	2.15	19.06
1956	.78	.16	1.27	1.66	2.06	1.06	.46	.95	.97	1.12	.52	.29	11.30
1957	.74	.20	1.16	1.27	2.80	4.68	1.52	.70	.85	1.46	.56	.58	16.52
1958	.82	.88	1.52	1.91	.37	2.43	3.25	2.52	1.40	.41	1.69	.91	18.11
1959	.79	1.12	1.58	1.37	4.08	2.42	1.53	.74	2.35	1.93	.90	.67	19.58
1960	.78	.71	1.77	2.32	2.33	1.18	.37	2.14	.43	.88	1.02	.68	14.61
1961	.11	.84	.82	2.49	1.39	.82	.71	.58	4.90	2.11	1.10	.25	16.12
1962	1.27	.49	1.32	1.12	3.86	1.55	3.08	2.14	.64	1.15	3.01	.34	19.97
1963	1.76	.53	1.06	1.98	3.29	3.13	1.09	.80	2.00	.94	.61	.67	17.86
1964	.48	.67	1.19	2.12	3.11	3.72	.91	3.80	.08	1.29	1.57	.91	19.94
1965	.97	.50	.45	2.24	4.16	3.76	.68	2.23	2.42	.45	.75	.61	19.22
1966	.75	.22	1.18	1.10	2.54	2.84	.46	1.26	1.08	1.53	.98	.69	14.63
1967	1.17	.76	3.28	1.45	2.05	4.44	1.12	.27	1.21	3.48	2.09	1.62	22.93
1968	.91	.44	2.13	1.42	4.03	3.78	1.08	2.63	2.77	1.37	2.65	.35	23.55
1969	1.95	.44	.46	2.51	1.92	7.37	1.70	1.50	.86	3.02	.58	1.09	23.40
1970	.70	.32	2.21	1.55	3.42	1.48	3.15	.97	2.23	1.58	1.41	.62	19.63
1971	.96	1.01	.74	2.82	2.20	2.86	.29	.70	2.41	.65	.77	.56	15.37
1972	.86	.66	1.24	1.91	1.73	3.07	1.20	1.44	2.00	2.59	.53	.49	17.32
1973	1.10	.04	1.89	2.84	1.44	4.43	.50	1.63	2.89	1.74	1.27	1.29	21.06
1974	.42	.43	1.71	1.87	3.00	.96	.48	2.65	1.46	1.60	.57	1.02	16.27
1975	1.58	1.11	1.08	1.77	4.88	3.46	1.89	1.13	1.67	4.29	1.33	1.10	25.28
1976	.60	.52	1.03	3.35	1.95	4.00	1.64	.79	3.29	1.77	.20	.22	19.36
1977	.60	.06	2.39	.57	3.84	2.21	2.24	2.13	2.88	1.44	1.19	1.19	20.73
1978	1.03	.87	.76	.93	4.04	2.11	2.17	.82	4.22	.81	1.87	.72	20.34
1979	1.03	.75	.77	1.92	2.33	3.66	.59	1.51	.07	1.54	.96	.30	15.43
1980	1.17	1.29	1.67	.39	5.68	2.85	1.12	1.85	3.40	.73	.77	.31	21.22
1981	.50	1.31	.99	1.99	6.99	3.96	1.14	.50	1.31	2.13	1.13	.75	22.70
1982	1.06	.78	2.80	2.20	2.88	4.04	1.52	1.01	2.92	1.34	.52	1.35	22.42
MEAN	.92	.69	1.47	1.77	2.71	3.05	1.21	1.29	1.80	1.53	1.10	.83	18.42
S.D.	.45	.37	.71	.81	1.43	1.51	.76	.82	1.17	.91	.69	.47	3.28
COEF. VAR.	.489	.538	.481	.456	.528	.495	.632	.639	.653	.595	.633	.571	.178
PERCENT OF ANNUAL MEAN	5.0%	3.8%	8.0%	9.6%	14.7%	16.6%	6.6%	7.0%	9.8%	8.3%	6.0%	4.5%	
SUM OF MONTHLY MEANS													18.4

Table IV.2

Consumptive Use - Alfalfa

CONSUMPTIVE USE ALFALFA

FILE -- COUSALZ
SITE -- BOZEMAN
UNIT -- IN
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE

10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	0.00	2.94	5.46	6.81	5.79	3.11	.19	0.00	0.00	24.30
1932	0.00	0.00	0.00	0.00	2.34	4.87	6.44	5.36	3.05	.17	0.00	0.00	22.22
1933	0.00	0.00	0.00	0.00	1.18	5.94	7.27	5.01	2.84	.20	0.00	0.00	22.44
1934	0.00	0.00	0.00	1.14	4.56	4.87	6.36	5.95	2.52	.19	0.00	0.00	26.09
1935	0.00	0.00	0.00	0.00	.65	4.55	6.58	5.38	3.34	.19	0.00	0.00	20.68
1936	0.00	0.00	0.00	0.00	4.32	5.46	7.90	5.75	3.05	.19	0.00	0.00	26.67
1937	0.00	0.00	0.00	0.00	2.51	4.55	6.67	5.40	3.30	.22	0.00	0.00	22.65
1938	0.00	0.00	0.00	0.00	1.01	4.99	6.09	5.23	3.35	.22	0.00	0.00	21.49
1939	0.00	0.00	0.00	0.00	3.81	4.01	6.46	5.36	3.05	.19	0.00	0.00	22.37
1940	0.00	0.00	0.00	0.00	3.18	5.37	6.77	5.73	3.33	.22	0.00	0.00	24.59
1941	0.00	0.00	0.00	0.00	2.76	4.87	6.34	5.36	2.21	.15	0.00	0.00	21.68
1942	0.00	0.00	0.00	0.00	0.00	3.95	6.30	5.23	2.95	.19	0.00	0.00	18.67
1943	0.00	0.00	0.00	0.00	.10	4.10	6.07	5.21	3.08	.21	0.00	0.00	18.77
1944	0.00	0.00	0.00	0.00	2.71	4.06	5.67	4.82	3.03	.22	0.00	0.00	20.50
1945	0.00	0.00	0.00	0.00	.32	3.79	6.21	5.44	2.64	.20	0.00	0.00	18.60
1946	0.00	0.00	0.00	0.00	.65	4.71	6.62	5.21	2.89	.15	0.00	0.00	20.22
1947	0.00	0.00	0.00	0.00	3.09	4.12	7.15	5.56	2.88	.21	0.00	0.00	23.00
1948	0.00	0.00	0.00	0.00	2.75	5.24	6.12	5.25	3.33	.40	0.00	0.00	23.09
1949	0.00	0.00	0.00	.36	3.79	4.53	6.60	6.06	1.45	0.00	0.00	0.00	22.79
1950	0.00	0.00	0.00	0.00	.54	4.45	5.63	4.88	3.03	.20	0.00	0.00	18.73
1951	0.00	0.00	0.00	0.00	2.09	3.66	6.44	4.80	2.37	0.00	0.00	0.00	19.36
1952	0.00	0.00	0.00	0.00	2.54	5.20	6.18	5.60	3.40	.44	0.00	0.00	23.36
1953	0.00	0.00	0.00	0.00	.55	4.77	7.08	5.91	3.55	1.42	0.00	0.00	23.27
1954	0.00	0.00	0.00	0.00	2.38	4.29	7.25	5.25	3.11	.06	0.00	0.00	22.34
1955	0.00	0.00	0.00	0.00	1.70	4.57	6.28	6.27	2.98	0.00	0.00	0.00	21.79
1956	0.00	0.00	0.00	0.00	2.44	5.67	6.59	4.95	3.46	1.22	0.00	0.00	24.42
1957	0.00	0.00	0.00	0.00	2.39	4.91	6.55	5.62	2.16	0.00	0.00	0.00	21.63
1958	0.00	0.00	0.00	0.00	4.80	4.95	5.63	5.91	2.99	1.26	0.00	0.00	25.54
1959	0.00	0.00	0.00	0.00	.80	5.48	6.65	5.32	2.67	0.00	0.00	0.00	20.92
1960	0.00	0.00	0.00	0.00	1.62	5.05	7.47	5.30	2.49	0.00	0.00	0.00	21.93
1961	0.00	0.00	0.00	0.00	2.41	6.45	7.27	6.38	1.88	0.00	0.00	0.00	24.39
1962	0.00	0.00	0.00	0.00	1.64	5.14	6.00	5.11	.47	0.00	0.00	0.00	18.36
1963	0.00	0.00	0.00	0.00	2.35	4.85	6.55	5.87	3.89	1.69	0.00	0.00	25.19
1964	0.00	0.00	0.00	0.00	2.05	4.57	7.35	4.99	1.17	0.00	0.00	0.00	20.13
1965	0.00	0.00	0.00	0.00	.77	4.75	6.30	4.99	1.17	0.00	0.00	0.00	17.98
1966	0.00	0.00	0.00	0.00	3.10	4.59	7.20	5.28	3.63	.85	0.00	0.00	24.65
1967	0.00	0.00	0.00	0.00	1.56	4.51	6.81	6.06	3.86	.29	0.00	0.00	23.09
1968	0.00	0.00	0.00	0.00	.77	4.63	6.53	4.58	2.08	0.00	0.00	0.00	18.59
1969	0.00	0.00	0.00	0.00	.09	3.84	4.41	6.34	6.02	3.49	0.00	0.00	24.19
1970	0.00	0.00	0.00	0.00	2.22	5.67	6.91	6.27	1.37	0.00	0.00	0.00	22.43
1971	0.00	0.00	0.00	0.00	2.47	4.79	6.23	6.69	1.87	0.00	0.00	0.00	22.05
1972	0.00	0.00	0.00	0.00	2.02	5.59	5.91	5.93	2.29	0.00	0.00	0.00	21.74
1973	0.00	0.00	0.00	0.00	2.13	5.16	6.86	5.87	2.82	.20	0.00	0.00	23.04
1974	0.00	0.00	0.00	0.00	1.34	6.14	7.40	5.09	3.01	.41	0.00	0.00	23.38
1975	0.00	0.00	0.00	0.00	.44	4.43	7.23	4.92	3.03	1.18	0.00	0.00	21.23
1976	0.00	0.00	0.00	0.00	3.54	4.85	6.91	5.30	3.37	.88	0.00	0.00	24.84
1977	0.00	0.00	0.00	0.00	2.23	5.90	6.32	5.23	3.04	.63	0.00	0.00	23.35
1978	0.00	0.00	0.00	0.00	1.62	5.12	6.37	5.40	3.32	.86	0.00	0.00	22.68
1979	0.00	0.00	0.00	0.00	2.27	5.37	6.89	5.73	4.01	.69	0.00	0.00	24.95
1980	0.00	0.00	0.00	0.00	3.74	5.16	6.65	4.94	3.19	.96	0.00	0.00	24.63
1981	0.00	0.00	0.00	0.00	2.15	4.67	6.67	6.29	3.53	.32	0.00	0.00	23.62
1982	0.00	0.00	0.00	0.00	1.13	4.93	6.60	6.06	2.89	.48	0.00	0.00	22.06
MEAN	0.00	0.00	0.00	.02	2.04	4.87	6.57	5.50	2.88	.40	0.00	0.00	22.33
S.D.	0.00	0.00	0.00	.16	1.18	.60	.57	.48	.86	.60	0.00	0.00	2.15
COEF. VAR.	+***.***	+***.***	+***.***	5.714	.580	.125	.087	.087	.301	1.476	+***.***	+***.***	.096
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	.1%	9.2%	21.8%	29.5%	24.6%	12.9%	1.8%	0.0%	0.0%	
SUM OF MONTHLY MEANS													22.3

Table IV. 3

Consumptive Use - Barley

CONSUMPTIVE USE BARLEY

FILE -- COUSBA2
SITE -- BOZEMAN
UNIT -- INCHES
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE 10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	.16	2.18	5.60	7.29	1.99	0.00	0.00	0.00	0.00	17.22
1932	0.00	0.00	0.00	.13	1.97	4.92	6.97	1.99	0.00	0.00	0.00	0.00	15.98
1933	0.00	0.00	0.00	0.00	.92	4.81	3.59	3.78	.22	0.00	0.00	0.00	13.32
1934	0.00	0.00	0.00	1.07	4.18	5.49	4.23	.20	0.00	0.00	0.00	0.00	15.17
1935	0.00	0.00	0.00	0.00	.78	3.55	7.77	4.33	.35	0.00	0.00	0.00	16.78
1936	0.00	0.00	0.00	.22	2.73	5.76	8.18	1.65	0.00	0.00	0.00	0.00	18.54
1937	0.00	0.00	0.00	0.00	1.71	4.21	7.56	2.90	.05	0.00	0.00	0.00	16.43
1938	0.00	0.00	0.00	0.00	1.17	4.40	7.01	3.23	.14	0.00	0.00	0.00	15.95
1939	0.00	0.00	0.00	.45	2.84	4.57	5.74	.90	0.00	0.00	0.00	0.00	14.50
1940	0.00	0.00	0.00	.13	2.27	5.43	7.33	2.13	0.00	0.00	0.00	0.00	17.29
1941	0.00	0.00	0.00	.13	2.09	4.92	6.87	1.99	0.00	0.00	0.00	0.00	16.00
1942	0.00	0.00	0.00	0.00	1.24	3.66	7.14	2.83	.05	0.00	0.00	0.00	14.92
1943	0.00	0.00	0.00	.42	1.91	4.67	5.40	.87	0.00	0.00	0.00	0.00	13.27
1944	0.00	0.00	0.00	.29	2.40	4.46	5.54	1.17	0.00	0.00	0.00	0.00	13.86
1945	0.00	0.00	0.00	0.00	.87	3.07	7.33	4.10	.21	0.00	0.00	0.00	15.58
1946	0.00	0.00	0.00	.65	2.18	5.42	5.08	.47	0.00	0.00	0.00	0.00	13.30
1947	0.00	0.00	0.00	.19	2.34	4.29	7.54	1.78	0.00	0.00	0.00	0.00	16.13
1948	0.00	0.00	0.00	.23	2.27	5.61	6.21	1.45	0.00	0.00	0.00	0.00	15.77
1949	0.00	0.00	0.00	.62	3.01	5.21	5.39	.66	0.00	0.00	0.00	0.00	14.89
1950	0.00	0.00	0.00	0.00	.97	3.73	6.65	3.42	.17	0.00	0.00	0.00	14.94
1951	0.00	0.00	0.00	.06	1.78	3.55	7.19	2.18	.02	0.00	0.00	0.00	14.78
1952	0.00	0.00	0.00	.44	2.46	5.92	5.50	.93	0.00	0.00	0.00	0.00	15.25
1953	0.00	0.00	0.00	0.00	.70	3.65	8.36	4.90	.44	0.00	0.00	0.00	18.05
1954	0.00	0.00	0.00	.23	2.19	4.59	7.36	1.48	0.00	0.00	0.00	0.00	15.85
1955	0.00	0.00	0.00	0.00	1.99	3.89	.01	0.00	0.00	0.00	0.00	0.00	5.89
1956	0.00	0.00	0.00	.06	1.82	5.53	7.45	2.13	.01	0.00	0.00	0.00	17.00
1957	0.00	0.00	0.00	.04	1.78	4.68	7.35	2.71	.02	0.00	0.00	0.00	16.58
1958	0.00	0.00	0.00	.17	2.86	5.08	6.02	2.03	0.00	0.00	0.00	0.00	16.16
1959	0.00	0.00	0.00	0.00	.89	4.58	7.78	3.32	.08	0.00	0.00	0.00	16.65
1960	0.00	0.00	0.00	0.00	1.53	4.96	8.05	1.69	0.00	0.00	0.00	0.00	16.23
1961	0.00	0.00	0.00	.02	1.68	6.06	9.20	3.24	.04	0.00	0.00	0.00	19.24
1962	0.00	0.00	0.00	.43	2.32	5.85	5.34	.85	0.00	0.00	0.00	0.00	14.79
1963	0.00	0.00	0.00	.09	1.86	4.76	7.26	2.50	.01	0.00	0.00	0.00	16.47
1964	0.00	0.00	0.00	0.00	1.63	4.45	7.98	1.63	0.00	0.00	0.00	0.00	15.69
1965	0.00	0.00	0.00	0.00	1.34	4.60	4.91	1.67	0.00	0.00	0.00	0.00	12.52
1966	0.00	0.00	0.00	.08	2.14	4.51	7.98	2.25	.01	0.00	0.00	0.00	16.97
1967	0.00	0.00	0.00	0.00	1.18	3.91	7.32	3.92	.15	0.00	0.00	0.00	17.08
1968	0.00	0.00	0.00	0.00	.96	4.06	7.42	2.16	.01	0.00	0.00	0.00	14.61
1969	0.00	0.00	0.00	.47	2.87	5.02	5.64	.99	0.00	0.00	0.00	0.00	14.99
1970	0.00	0.00	0.00	0.00	1.32	4.92	8.03	4.05	.12	0.00	0.00	0.00	18.43
1971	0.00	0.00	0.00	.06	1.83	4.64	6.96	3.03	.02	0.00	0.00	0.00	16.54
1972	0.00	0.00	0.00	.04	1.64	5.33	6.64	2.85	.02	0.00	0.00	0.00	16.52
1973	0.00	0.00	0.00	0.00	1.52	4.70	7.81	3.31	.07	0.00	0.00	0.00	17.41
1974	0.00	0.00	0.00	.42	2.12	7.00	6.58	.88	0.00	0.00	0.00	0.00	17.00
1975	0.00	0.00	0.00	0.00	.67	3.32	8.53	4.20	.39	0.00	0.00	0.00	17.11
1976	0.00	0.00	0.00	.24	2.62	5.18	7.01	1.49	0.00	0.00	0.00	0.00	16.54
1977	0.00	0.00	0.00	.59	2.50	6.79	5.16	.58	0.00	0.00	0.00	0.00	15.62
1978	0.00	0.00	0.00	.32	2.14	5.67	6.09	1.14	0.00	0.00	0.00	0.00	15.36
1979	0.00	0.00	0.00	.10	1.88	5.36	7.54	2.28	.01	0.00	0.00	0.00	17.17
1980	0.00	0.00	0.00	.54	2.91	5.92	5.59	.69	0.00	0.00	0.00	0.00	15.64
1981	0.00	0.00	0.00	.35	2.33	5.22	6.25	1.25	0.00	0.00	0.00	0.00	15.40
1982	0.00	0.00	0.00	0.00	1.03	4.13	7.79	4.23	.18	0.00	0.00	0.00	17.36
MEAN	0.00	0.00	0.00	.19	1.99	4.83	6.75	2.16	.05	0.00	0.00	0.00	15.98
S.D.	0.00	0.00	0.00	.23	.71	.84	1.43	1.22	.10	0.00	0.00	0.00	1.94
COEF. VAR.	+***.***	+***.***	+***.***	1.278	.377	.173	.212	.565	1.933	+***.***	+***.***	+***.***	.122
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	1.1%	11.9%	30.5%	42.5%	13.6%	.3%	0.0%	0.0%	0.0%	
SUM OF MONTHLY MEANS													15.9

Table IV. 4

Effective Precipitation - Barley

EFFECTIVE PRECIP. BARLEY

FILE -- EFPREC82
SITE -- BOZEMAN
UNIT -- IN
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE 10/09/84

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	.28	2.23	1.50	1.46	.37	0.00	0.00	0.00	0.00	5.34
1932	0.00	0.00	0.00	.51	.69	3.29	1.55	1.54	0.00	0.00	0.00	0.00	7.58
1933	0.00	0.00	0.00	0.00	1.90	1.13	.40	3.48	.94	0.00	0.00	0.00	7.85
1934	0.00	0.00	0.00	.17	.83	2.35	.40	0.00	0.00	0.00	0.00	0.00	3.80
1935	0.00	0.00	0.00	0.00	1.59	1.76	.77	.70	0.00	0.00	0.00	0.00	4.82
1936	0.00	0.00	0.00	.28	1.31	2.13	0.00	1.38	0.00	0.00	0.00	0.00	5.10
1937	0.00	0.00	0.00	0.00	.82	3.90	2.16	.20	.54	0.00	0.00	0.00	7.61
1938	0.00	0.00	0.00	0.00	5.09	1.82	1.20	.83	0.00	0.00	0.00	0.00	8.99
1939	0.00	0.00	0.00	.53	1.91	3.71	.69	.67	0.00	0.00	0.00	0.00	7.51
1940	0.00	0.00	0.00	.67	1.38	2.99	.61	.45	0.00	0.00	0.00	0.00	6.10
1941	0.00	0.00	0.00	.70	1.45	3.17	1.26	1.80	.15	0.00	0.00	0.00	8.53
1942	0.00	0.00	0.00	0.00	2.44	2.68	.47	.53	.36	0.00	0.00	0.00	6.48
1943	0.00	0.00	0.00	1.64	2.10	2.50	1.90	.88	0.00	0.00	0.00	0.00	9.02
1944	0.00	0.00	0.00	.24	3.00	7.98	1.70	1.19	0.00	0.00	0.00	0.00	14.11
1945	0.00	0.00	0.00	0.00	2.72	4.10	.76	1.73	.92	0.00	0.00	0.00	10.23
1946	0.00	0.00	0.00	1.00	3.03	1.38	1.47	.42	0.00	0.00	0.00	0.00	7.30
1947	0.00	0.00	0.00	.37	1.05	6.78	.37	.77	0.00	0.00	0.00	0.00	9.34
1948	0.00	0.00	0.00	.68	2.37	4.87	1.58	1.73	0.00	0.00	0.00	0.00	11.23
1949	0.00	0.00	0.00	1.30	1.92	3.73	.51	.34	0.00	0.00	0.00	0.00	7.80
1950	0.00	0.00	0.00	0.00	1.67	2.16	2.74	1.86	.86	0.00	0.00	0.00	9.29
1951	0.00	0.00	0.00	.18	1.52	1.61	.87	2.36	.30	0.00	0.00	0.00	6.84
1952	0.00	0.00	0.00	1.06	6.63	2.02	1.28	.82	0.00	0.00	0.00	0.00	11.81
1953	0.00	0.00	0.00	0.00	2.08	3.13	.63	.42	.60	0.00	0.00	0.00	6.86
1954	0.00	0.00	0.00	.15	1.70	3.70	.66	1.19	0.00	0.00	0.00	0.00	7.40
1955	0.00	0.00	0.00	0.00	2.35	2.23	0.00	0.00	0.00	0.00	0.00	0.00	4.58
1956	0.00	0.00	0.00	.17	2.06	1.06	.46	.95	0.00	0.00	0.00	0.00	4.70
1957	0.00	0.00	0.00	0.00	2.80	4.69	1.52	.70	.14	0.00	0.00	0.00	9.84
1958	0.00	0.00	0.00	.45	.37	2.43	3.25	2.52	0.00	0.00	0.00	0.00	9.02
1959	0.00	0.00	0.00	0.00	3.03	2.42	1.63	.74	.71	0.00	0.00	0.00	8.53
1960	0.00	0.00	0.00	0.00	2.33	1.18	.37	1.93	0.00	0.00	0.00	0.00	5.81
1961	0.00	0.00	0.00	0.00	1.39	.82	.71	.58	.18	0.00	0.00	0.00	3.68
1962	0.00	0.00	0.00	.60	3.86	1.55	3.08	1.52	0.00	0.00	0.00	0.00	10.61
1963	0.00	0.00	0.00	.26	3.29	3.13	1.09	.80	.20	0.00	0.00	0.00	8.77
1964	0.00	0.00	0.00	0.00	3.11	3.72	.91	3.55	0.00	0.00	0.00	0.00	11.29
1965	0.00	0.00	0.00	0.00	4.16	3.76	.68	2.16	0.00	0.00	0.00	0.00	10.76
1966	0.00	0.00	0.00	.15	2.54	2.84	.46	1.26	0.00	0.00	0.00	0.00	7.25
1967	0.00	0.00	0.00	0.00	1.79	4.44	1.12	.27	.44	0.00	0.00	0.00	8.06
1968	0.00	0.00	0.00	0.00	3.12	3.79	1.08	2.63	.28	0.00	0.00	0.00	10.39
1969	0.00	0.00	0.00	1.34	1.92	7.37	1.70	1.06	0.00	0.00	0.00	0.00	13.39
1970	0.00	0.00	0.00	0.00	2.98	1.48	3.15	.97	.82	0.00	0.00	0.00	9.40
1971	0.00	0.00	0.00	.28	2.20	2.86	.29	.70	.32	0.00	0.00	0.00	6.65
1972	0.00	0.00	0.00	.13	1.73	3.07	1.20	1.44	.33	0.00	0.00	0.00	7.90
1973	0.00	0.00	0.00	0.00	1.44	4.43	.50	1.63	.77	0.00	0.00	0.00	8.77
1974	0.00	0.00	0.00	1.00	3.00	.96	.48	1.88	0.00	0.00	0.00	0.00	7.32
1975	0.00	0.00	0.00	0.00	2.99	3.46	1.89	1.13	1.06	0.00	0.00	0.00	10.53
1976	0.00	0.00	0.00	1.12	1.95	4.00	1.64	.71	0.00	0.00	0.00	0.00	9.42
1977	0.00	0.00	0.00	.36	3.84	2.21	2.24	1.31	0.00	0.00	0.00	0.00	9.96
1978	0.00	0.00	0.00	.40	4.04	2.11	2.17	.66	0.00	0.00	0.00	0.00	9.38
1979	0.00	0.00	0.00	.32	2.33	3.66	.59	1.51	0.00	0.00	0.00	0.00	8.41
1980	0.00	0.00	0.00	.23	5.68	2.85	1.12	1.19	0.00	0.00	0.00	0.00	11.07
1981	0.00	0.00	0.00	.93	6.99	3.96	1.14	.39	0.00	0.00	0.00	0.00	13.41
1982	0.00	0.00	0.00	0.00	2.32	4.04	1.52	1.01	1.27	0.00	0.00	0.00	10.16
MEAN	0.00	0.00	0.00	.33	2.52	3.05	1.18	1.17	.21	0.00	0.00	0.00	8.48
S.D.	0.00	0.00	0.00	.42	1.35	1.51	.78	.78	.34	0.00	0.00	0.00	2.38
COEF. VAR.	****.***	****.***	****.***	1.257	.538	.495	.665	.673	1.598	****.***	****.***	****.***	.280
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	4.0%	29.7%	36.0%	13.9%	13.8%	2.5%	0.0%	0.0%	0.0%	

SUM OF MONTHLY MEANS 8.5

Table IV.5

Effective Precipitation - Alfalfa

EFFECTIVE PRECIP. ALFALFA

FILE -- EFPRECA2
SITE -- BOZEMAN
UNIT -- IN
NOTE -- ANY MONTH WITH ****.** INDICATES NO DATA AVAILABLE 10/09/94

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1931	0.00	0.00	0.00	0.00	1.73	1.50	1.46	.37	2.13	0.00	0.00	0.00	7.19
1932	0.00	0.00	0.00	0.00	.45	3.29	1.55	1.56	.21	.22	0.00	0.00	7.26
1933	0.00	0.00	0.00	0.00	.83	1.13	.40	3.48	1.97	.17	0.00	0.00	7.38
1934	0.00	0.00	0.00	0.00	.38	2.35	.40	0.00	1.06	.14	0.00	0.00	4.33
1935	0.00	0.00	0.00	0.00	.45	1.76	.77	.70	.15	.23	0.00	0.00	4.06
1936	0.00	0.00	0.00	0.00	1.31	2.13	0.00	1.48	1.04	0.00	0.00	0.00	5.96
1937	0.00	0.00	0.00	0.00	.56	3.90	2.16	.20	2.33	0.00	0.00	0.00	9.15
1938	0.00	0.00	0.00	0.00	1.63	1.82	1.20	.88	0.00	.30	0.00	0.00	5.83
1939	0.00	0.00	0.00	0.00	1.31	3.71	.69	.94	1.29	0.00	0.00	0.00	7.54
1940	0.00	0.00	0.00	0.00	1.11	2.99	.61	.45	2.48	0.00	0.00	0.00	7.64
1941	0.00	0.00	0.00	0.00	1.08	3.17	1.26	1.80	4.60	0.00	0.00	0.00	11.91
1942	0.00	0.00	0.00	0.00	0.00	2.68	.47	.53	1.56	.12	0.00	0.00	5.36
1943	0.00	0.00	0.00	0.00	0.00	2.50	1.30	1.24	.91	.19	0.00	0.00	6.74
1944	0.00	0.00	0.00	0.00	2.32	7.98	1.70	1.42	2.13	0.00	0.00	0.00	15.55
1945	0.00	0.00	0.00	0.00	.36	4.10	.76	1.73	1.84	0.00	0.00	0.00	8.79
1946	0.00	0.00	0.00	0.00	.59	1.38	1.47	.76	1.37	.23	0.00	0.00	5.60
1947	0.00	0.00	0.00	0.00	.88	6.78	.37	.80	4.58	0.00	0.00	0.00	13.41
1948	0.00	0.00	0.00	0.00	1.76	4.87	1.58	1.91	.60	0.00	0.00	0.00	10.72
1949	0.00	0.00	0.00	.27	1.92	3.73	.51	.55	.88	0.00	0.00	0.00	7.35
1950	0.00	0.00	0.00	0.00	.33	2.16	2.74	1.86	1.99	0.00	0.00	0.00	9.08
1951	0.00	0.00	0.00	0.00	.93	1.61	.37	2.36	2.01	0.00	0.00	0.00	7.78
1952	0.00	0.00	0.00	0.00	4.71	2.02	1.28	1.16	.56	0.00	0.00	0.00	9.73
1953	0.00	0.00	0.00	0.00	.52	3.13	.63	.42	1.00	.99	0.00	0.00	6.69
1954	0.00	0.00	0.00	0.00	1.15	3.70	.66	1.32	1.21	0.00	0.00	0.00	8.04
1955	0.00	0.00	0.00	0.00	1.31	2.23	1.55	.12	1.11	0.00	0.00	0.00	6.32
1956	0.00	0.00	0.00	0.00	1.33	1.06	.46	.95	.97	.43	0.00	0.00	5.20
1957	0.00	0.00	0.00	0.00	1.31	4.68	1.52	.70	.54	0.00	0.00	0.00	9.25
1958	0.00	0.00	0.00	0.00	.37	2.43	3.25	2.52	1.40	.28	0.00	0.00	10.25
1959	0.00	0.00	0.00	0.00	.92	2.42	1.63	.74	2.27	0.00	0.00	0.00	7.98
1960	0.00	0.00	0.00	0.00	1.05	1.18	.37	2.14	.32	0.00	0.00	0.00	5.06
1961	0.00	0.00	0.00	0.00	.85	.82	.71	.53	3.59	0.00	0.00	0.00	6.55
1962	0.00	0.00	0.00	0.00	1.76	1.55	3.08	2.14	0.00	0.00	0.00	0.00	8.51
1963	0.00	0.00	0.00	0.00	2.12	3.13	1.09	.80	2.00	.73	0.00	0.00	9.87
1964	0.00	0.00	0.00	0.00	1.81	3.72	.91	3.80	0.00	0.00	0.00	0.00	10.24
1965	0.00	0.00	0.00	0.00	.96	3.76	.68	2.23	1.29	0.00	0.00	0.00	8.90
1966	0.00	0.00	0.00	0.00	2.05	2.84	.46	1.26	1.08	.69	0.00	0.00	8.38
1967	0.00	0.00	0.00	0.00	.93	4.44	1.12	.27	1.21	.45	0.00	0.00	8.42
1968	0.00	0.00	0.00	0.00	.91	3.78	1.08	2.63	1.94	0.00	0.00	0.00	10.34
1969	0.00	0.00	0.00	0.00	1.92	7.37	1.70	1.50	.86	.49	0.00	0.00	13.84
1970	0.00	0.00	0.00	0.00	1.99	1.48	3.15	.97	.97	0.00	0.00	0.00	8.56
1971	0.00	0.00	0.00	0.00	1.49	2.86	.29	.70	1.45	0.00	0.00	0.00	6.79
1972	0.00	0.00	0.00	0.00	.95	3.07	1.20	1.44	1.60	0.00	0.00	0.00	8.26
1973	0.00	0.00	0.00	0.00	.84	4.43	.50	1.63	2.89	.17	0.00	0.00	10.46
1974	0.00	0.00	0.00	0.00	1.06	.96	.48	2.65	1.46	.31	0.00	0.00	6.92
1975	0.00	0.00	0.00	0.00	.63	3.46	1.39	1.13	1.67	3.18	0.00	0.00	11.96
1976	0.00	0.00	0.00	0.00	1.76	4.00	1.64	.79	3.29	.86	0.00	0.00	12.34
1977	0.00	0.00	0.00	0.00	2.35	2.21	2.24	2.13	2.88	.46	0.00	0.00	12.27
1978	0.00	0.00	0.00	0.00	1.82	2.11	2.17	.82	4.22	.34	0.00	0.00	11.48
1979	0.00	0.00	0.00	0.00	1.43	3.66	.59	1.51	0.00	.45	0.00	0.00	7.64
1980	0.00	0.00	0.00	0.00	5.68	2.85	1.12	1.85	3.40	.38	0.00	0.00	15.28
1981	0.00	0.00	0.00	0.00	4.28	3.96	1.14	.50	1.31	.34	0.00	0.00	11.53
1982	0.00	0.00	0.00	0.00	.93	4.04	1.52	1.01	2.32	.35	0.00	0.00	10.77
MEAN	0.00	0.00	0.00	.00	1.39	3.05	1.21	1.29	1.63	.24	0.00	0.00	8.34
S.D.	0.00	0.00	0.00	.03	1.06	1.51	.76	.83	1.14	.48	0.00	0.00	2.42
COEF. VAR.	+***.***	+***.***	+***.***	7.211	.761	.495	.635	.641	.698	2.011	+***.***	+***.***	.287
PERCENT OF ANNUAL MEAN	0.0%	0.0%	0.0%	.1%	15.8%	36.6%	13.7%	14.7%	18.5%	2.7%	0.0%	0.0%	
SUM OF MONTHLY MEANS													8.8

Table IV.6

Weighted Net Irrigation Requirement

WEIGHTED IRRIGATION REQUIREMENT

FILE -- IWIR2WYR
SITE -- MIDDLE CREEK AVAILABILITY
UNIT -- INCHES
NOTE -- ANY MONTH WITH ******.* INDICATES NO DATA AVAILABLE 10/10/84

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL TOTAL
1931	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.7	4.0	5.5	3.9	.6	14.9
1932	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.5	5.0	2.5	1.7	12.7
1933	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	4.3	7.3	1.0	.6	13.6
1934	.0	0.0	0.0	0.0	0.0	0.0	1.0	3.5	2.7	5.4	3.7	.9	17.5
1935	.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	2.4	6.2	4.2	2.1	15.2
1936	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	3.4	8.0	2.7	1.2	17.3
1937	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.5	.5	4.8	4.2	.6	11.9
1938	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	5.2	3.6	2.5	14.4
1939	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	.5	5.5	2.8	1.1	11.4
1940	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.4	6.3	3.9	.5	14.9
1941	.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.7	5.2	2.2	0.0	10.7
1942	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	6.1	3.8	.9	12.1
1943	.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.8	3.9	2.4	1.3	9.5
1944	.0	0.0	0.0	0.0	0.0	0.0	.0	.2	0.0	3.9	2.1	.5	6.8
1945	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	3.2	.5	9.7
1946	.1	0.0	0.0	0.0	0.0	0.0	0.0	.0	3.5	4.5	2.8	.5	11.7
1947	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	6.9	3.3	0.0	12.1
1948	.1	0.0	0.0	0.0	0.0	0.0	0.0	.6	.5	4.5	2.0	1.7	9.6
1949	.2	0.0	0.0	0.0	0.0	0.0	.0	1.5	1.0	5.6	3.5	.3	12.4
1950	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	2.0	3.2	2.4	.6	9.5
1951	.1	0.0	0.0	0.0	0.0	0.0	0.0	.8	2.0	5.8	1.5	.2	10.5
1952	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	4.6	2.8	1.7	12.6
1953	.2	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.2	6.9	5.1	1.5	15.1
1954	.2	0.0	0.0	0.0	0.0	0.0	.0	.9	.7	5.6	2.5	1.1	12.3
1955	.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	2.0	2.9	3.8	1.1	10.3
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	4.5	6.5	2.9	1.5	16.2
1957	.2	0.0	0.0	0.0	0.0	0.0	.0	.3	.1	5.3	3.8	1.0	10.9
1958	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	2.5	2.5	2.1	.9	11.9
1959	.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	5.4	3.8	.2	12.9
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	3.8	7.3	1.9	1.3	14.9
1961	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.0	5.4	6.9	4.6	0.0	19.1
1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	2.6	1.8	.2	9.5
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	1.6	5.7	3.8	1.1	12.5
1964	.6	0.0	0.0	0.0	0.0	0.0	0.0	.1	.8	6.6	.7	.7	9.7
1965	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.9	5.8	1.7	0.0	8.5
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	1.7	7.0	2.8	1.5	13.9
1967	.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.0	6.1	4.9	1.6	13.2
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	5.7	1.2	.0	7.7
1969	0.0	0.0	0.0	0.0	0.0	0.0	.0	1.5	0.0	4.3	2.8	1.6	10.4
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	3.9	4.1	4.4	.2	12.9
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5	1.8	5.2	4.6	.2	13.5
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	2.4	4.9	3.3	.4	11.9
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	.5	5.7	3.2	0.0	11.3
1974	.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	5.5	6.6	1.5	.9	14.9
1975	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	5.8	3.5	.8	10.3
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	.9	5.3	3.1	.0	10.9
1977	.0	0.0	0.0	0.0	0.0	0.0	.0	0.0	4.0	3.6	1.9	.0	9.3
1978	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	4.0	3.0	0.0	10.4
1979	.3	0.0	0.0	0.0	0.0	0.0	0.0	.5	1.7	6.5	2.9	2.5	14.5
1980	.1	0.0	0.0	0.0	0.0	0.0	.1	0.0	2.5	5.1	1.9	0.0	9.9
1981	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.9	5.3	3.9	1.3	11.9
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.5	5.5	4.3	0.0	10.5
MEAN	.0	0.0	0.0	0.0	0.0	0.0	.0	.6	2.0	5.4	3.0	.8	12.1
S.D.	.1	0.0	0.0	0.0	0.0	0.0	.1	.8	1.4	1.2	1.0	.6	2.5
COEF. VAR.	1.532	****.***	****.***	****.***	****.***	****.***	5.127	1.287	.744	.224	.342	.920	.208
PERCENT OF ANNUAL MEAN	.3%	0.0%	0.0%	0.0%	0.0%	0.0%	.2%	5.5%	16.5%	45.1%	25.1%	6.9%	
SUM OF MONTHLY MEANS													12.2

only climatological data are available. The net amount of irrigation water necessary to satisfy consumptive use is found by subtracting the effective precipitation from the consumptive water requirement.

Numerous climatic factors must be taken into consideration if the net consumptive use of water is to be determined accurately. Of the climatic factors, the effect of temperature, hours of sunshine available for plant growth and effective precipitation are the most important. Other influencing factors, not directly considered by the Blaney-Criddle equation, are:

- Actual radiation energy received by the plant
- Relative humidity
- Wind speed
- Altitude
- Advection
- Soil Factors
- Plant Factors

The general effect of varying seasonal radiation can be introduced by computing the length of sunshine during the growing season at various latitudes. As an example, the length of the daytime at the equator varies little throughout the year, whereas at 50°N. latitude, the length of the day in summer is much longer than in winter. Thus, at equal temperatures, photosynthesis can take place for several hours longer each June day at the north latitude than at the equator. Growth and water consumption vary with the opportunity for photosynthesis.

The Blaney/Criddle Formula

Disregarding many other influencing factors, consumptive use primarily varies with the temperature, length of day, and available moisture regardless of its source (precipitation, irrigation water, or natural ground water). Multiplying the mean monthly temperature (t) by the possible monthly percentage of daytime hours of the year (p) gives a monthly consumptive-use factor (f). It is assumed that crop consumptive use varies directly with this factor when an ample water supply is available. Expressed mathematically:

u	=	kf, where,
u	=	Monthly consumptive use of the plants in inches.
k	=	Empirical consumptive use coefficient for a month
f	=	Monthly consumptive use factor (product of mean monthly temperature and monthly percentage of daylight hours of the year).
f	=	t x p, where
t	=	Mean monthly air temperature in degrees Fahrenheit
p	=	Monthly percentage of daylight hours in the year. Values of (p) for latitudes 0 to 65 degrees north of the Equator can be found in tables in TR-21 (SCS, 1970).

And:

U	=	KF = sum of kf, where,
U	=	Consumptive use in inches for the growing season
K	=	Empirical consumptive use coefficient for the growing season. This coefficient varies with the different vegetation being considered.

F = Sum of the monthly consumptive use factors for the growing season (sum of the products of mean monthly temperature and monthly percentage of daylight hours of the year).

Note: Values of (t), (p), (f), and (k), can also be made to apply to shorter periods. However, we have found the formula to be most accurate on a seasonal basis.

Following are modifications made to the original formula by the SCS:

k = k_t x k_c, where,

k_t = A climatic coefficient which is related to the mean air temperature (t). Values of k_t for mean air temperatures from 36 to 100 degrees are shown in Table 4 in TR-21 (SCS, 1970).

k_c = A coefficient reflecting the growth stage of the plants. Values are obtained from growth stage coefficient curves given in TR-21 (SCS, 1970) or developed by HKM Associates.

The consumptive use factor (F) may be computed for areas for which monthly temperature records are available. Then, the total crop consumptive use (U) is obtained by multiplying (F) by the empirical consumptive use crop coefficient (K). This relationship allows the computation of seasonal consumptive use at any location for those plants for which values of (K) have been experimentally established or can be estimated.

Growing Season

In utilizing the Blaney-Criddle formula for computing seasonal requirements, the potential growing season for the various species is normally considered to extend from killing frost to killing frost or from the last killing frost in the spring to

the end of a definite period of time thereafter. For most crops, this is adequate for seasonal use estimates, but a refinement is necessary to more precisely define the growing season when monthly or short-time use estimates are required. In many areas, records are available from which planting, harvesting and growth dates can be determined. These should be used where possible. In other areas, temperature data may be helpful for estimating these dates. Table IV.7 contains some guides which are helpful in determining these dates.

Since the spring frost date corresponds very nearly with a mean temperature of 55 degrees, it is obvious that many of the common plants use appreciable amounts of water prior to the last frost in the spring and may continue to use water after the first frost in the fall. If non-growing season precipitation is significant it may be necessary to analyze the consumptive use for the entire year. Non-growing season soil moisture gains can be used by the plant growth during the growing season reducing irrigation requirements. Non-growing season moisture gains were not considered in this analysis so that irrigation demands would remain conservatively high.

Table IV.7. A Guide for Determining Planting Dates, Maturity Dates and Lengths of Growing Seasons as Related to Mean Air Temperature

Crop	Earliest Moisture use or planting date as related to mean air temperature	Latest Moisture use or maturing date as related to mean air temperature	Growing Season days
Perennial Crops			
Alfalfa	50° mean temp	28° frost	Variable
Grasses, cool	45° mean temp	45° mean temp	Variable
Annual Crops			
Grain, spring	45° mean temp	32° frost	130 - Max.

Source: TR-21 (SCS, 1970)

Growth Stage Coefficients

As previously stated, another factor which causes consumptive use to vary widely throughout the growing season is the plant itself. Stage of growth is a primary variable that must be recognized since it is obvious that plants in the higher level of maturity will use water at a more rapid rate than will new seedlings. It is also obvious that these variations in consumptive use throughout the growing season will be greater for annual plants than for perennial plants such as alfalfa, permanent pasture grasses, deciduous trees, willows and others.

To recognize these variations in consumptive use, plant growth stage coefficients (k_c) have been introduced into the formula. Values of these coefficients are calculated from research data. When values of (k_c) are plotted against time or stage of growth curves, can be developed. Such curves are used to obtain values of (k_c) which, when used with appropriate values of (k_t), will permit a determination of values of monthly or short-time consumptive use coefficients (k).

It is also recognized that value of (k_c) might, to some extent, be influenced by factors other than the characteristics of the plant itself. For this reason, it is not expected that these curves can be used universally. They should, however, be valid over a considerable area and certainly should be of value in areas where no measured consumptive-use is available. However, coefficients developed and calibrated specifically for the area under consideration will give better results.

SURFACE WATER SUPPLY

The report Hydrologic Potential For The Hyalite Creek Watershed (HKM, 1983) addresses watershed yield without storage effects. The following paragraphs summarize this study.

A suitable study period used in establishing the hydrologic potential for the Hyalite Creek watershed was determined to be 1931 through 1982. Given long term climatic precipitation data, the selected study period appears to be slightly above a long term average or "surplus." The period does include the widely recognized sustained dry period during the 1930's. Also included in the study period is a sustained surplus period through the 1960's and 1970's, and average conditions particularly during the 1940 to 1960 timespan. The study period does exhibit strong persistence similar to longer record periods. The above comments relating to climate conditions are assumed applicable to corresponding hydrologic conditions because precipitation is the primary input to runoff. The period 1931-82 is acceptably representative of long-term hydrologic conditions.

The hydrologic potential analysis focused on two primary locations of interest within the Hyalite Creek Watershed: Hyalite Creek at Hyalite Ranger Station, which is near the mouth of Hyalite Canyon, and Hyalite Creek at Middle Creek Dam. Monthly sequential streamflows were generated for the period 1931-82. The long-term mean monthly, unregulated flow for Hyalite Creek near the canyon mouth is estimated to be 46,708 AF. The 50% chance and 80% chance flows at this location are 45,610 AF and 37,532 AF, respectively. Relative to Hyalite Creek at the dam (also referred to as reservoir inflows), the long-term mean annual flow is estimated to be 34,768 AF. The 50% chance flow is 34,009 AF and the 80% chance flow is 27,346 AF. See Tables IV.8 and IV.9 for a tabulation of monthly streamflows.

Table IV.8

Monthly Streamflow (Estimated)
At Middle Creek Dam

MONTHLY STREAMFLOW (ESTIMATED)

FILE -- MCFINAL
SITE -- MIDDLE CREEK DAM INFLOW
UNIT -- AC-FT
NOTE -- ANY MONTH WITH ******* INDICATES NO DATA AVAILABLE 10/09/84

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL TOTAL
1931	1801	1126	979	602	935	1096	1639	5383	6328	1546	967	700	23264
1932	744	972	948	873	825	849	1134	7069	13864	4247	1733	1355	34617
1933	1238	1035	855	923	750	825	1244	3259	11022	2998	1634	1343	27133
1934	1039	945	944	967	817	963	1953	3722	2207	1152	866	528	16109
1935	694	565	321	233	264	367	638	5079	11000	5596	1787	938	27489
1936	808	638	606	425	306	481	2903	5629	4019	1269	986	767	18845
1937	800	663	581	469	311	455	752	6592	7376	2402	1018	905	22329
1938	840	590	445	475	349	541	1447	6357	8629	2968	1577	978	25201
1939	1139	929	840	694	422	614	1827	6597	6033	3553	1431	1083	25323
1940	938	646	574	654	355	629	1262	8192	9471	3114	1423	1107	29171
1941	1051	694	614	776	606	736	1286	5241	5710	1997	1220	2522	22458
1942	2385	1423	1286	969	565	743	3025	5685	8509	6251	1965	1333	34146
1943	1229	1035	776	719	637	606	3025	6033	11226	6430	2029	1253	35054
1944	1229	1156	767	654	638	606	800	6263	11049	5920	1972	1903	32973
1945	1608	962	694	638	638	574	733	6486	9467	7231	1997	1512	32577
1946	1431	1196	1051	939	889	945	3534	5346	7190	4286	2134	1601	30496
1947	1415	1286	856	590	690	552	1593	9973	11299	7724	2790	2426	40999
1948	1997	1318	1253	1213	606	945	5645	14195	12553	4917	3461	2200	50307
1949	1779	1552	1237	727	760	692	2272	6794	7699	3130	1471	1504	29423
1950	1391	969	873	654	687	687	1213	4674	9592	5960	2482	1633	30821
1951	1415	1213	1156	962	551	277	2296	8201	5289	4003	1859	1431	28657
1952	1406	949	736	1013	606	654	2952	9327	11136	4480	2151	1350	37221
1953	1067	760	767	691	926	637	1350	4319	10668	5872	1656	1366	30093
1954	1244	945	996	675	795	1023	1415	6122	8338	5346	2127	1067	29900
1955	832	677	1068	798	574	589	744	6373	10603	4723	1876	913	29776
1956	1140	660	859	679	655	686	1931	5467	9390	2409	1326	1253	26310
1957	1148	875	825	540	635	682	931	5670	12423	4327	1520	1326	30706
1958	1131	840	816	792	625	655	1375	9374	7061	3380	1868	1196	29119
1959	1002	938	816	776	505	679	1657	7263	15788	7020	2127	1319	40394
1960	1883	1455	1018	825	808	945	2571	5791	10927	4554	2102	1173	34057
1961	936	881	552	321	569	682	1213	5379	7392	1633	1164	1269	22045
1962	1997	1067	783	657	637	776	3664	7344	9585	5581	2733	1763	36591
1963	1528	601	1253	703	805	954	1965	9261	11016	4512	2143	1471	36216
1964	1204	881	545	323	385	500	1939	9123	12464	7877	2790	1795	39882
1965	1593	969	1479	1035	808	1027	1674	8467	15464	10385	3178	2571	43656
1966	1933	1454	1100	905	796	864	1722	8993	8323	4117	2272	1318	33798
1967	1406	856	1013	741	591	780	969	8201	14339	7377	2207	1495	40532
1968	1803	1471	1237	1083	849	1051	1309	8961	14858	10288	4787	3429	51132
1969	2968	1479	1042	1180	736	1035	3558	14235	11638	8112	2498	1916	50453
1970	1714	1075	1115	889	945	954	855	14090	20164	9252	3347	2628	57045
1971	2240	1584	1011	885	1027	1011	1471	10248	14785	9405	3485	2451	49608
1972	2118	1350	861	857	834	1431	1795	7036	10135	4505	1431	1601	33960
1973	1617	1107	783	535	530	1087	775	10668	12172	5561	1908	1997	38845
1974	1520	1489	921	1156	698	703	2167	8079	18667	8032	2555	1941	47931
1975	1907	1946	1546	1442	1084	1108	1079	3896	17914	18717	3694	1972	56207
1976	2038	1506	1180	923	697	671	1311	8348	12693	9164	2919	1773	43229
1977	1707	994	802	703	520	607	1941	5561	10320	3115	1552	1521	29148
1978	1815	1167	884	820	778	839	1404	5196	11707	10867	2536	1831	39850
1979	1274	1145	932	1049	772	1013	1168	7007	12754	5890	1930	1683	36673
1980	2065	1824	1920	1461	901	793	2859	9054	9480	3504	1792	1915	37574
1981	1373	1217	1124	923	554	698	1556	7569	11719	5293	1722	1195	34930
1982	1324	1014	853	1285	1074	1066	1151	5233	11877	9565	2903	2245	39595
MEAN	1462	1075	934	800	670	765	1736	7289	10682	5620	2098	1582	34768
S.D.	472	320	284	265	199	234	952	2469	3528	3128	779	558	9349
COEF. VAR.	.323	.297	.304	.331	.298	.306	.533	.338	.330	.556	.371	.352	.268
PERCENT OF ANNUAL MEAN	4.2%	3.1%	2.7%	2.3%	1.9%	2.2%	5.1%	21.0%	30.7%	16.2%	6.0%	4.6%	

SUM OF MONTHLY MEANS 34,763.1

Table IV. 9

Monthly Streamflows
At Hyalite Ranger Station

MONTHLY STREAMFLOWS

FILE -- HYURESE4
SITE -- HYALITE CR. (MIDDLE CR. NEAR BOZEMAN) AT HYALITE RANGER STA.
UNIT -- AC-FT
NOTE -- ANY MONTH WITH ****** INDICATES NO DATA AVAILABLE 10/09/94

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL TOTAL
1931	2537	1704	1521	1055	1468	1665	2399	6973	3134	2346	1506	1177	32486
1932	1231	1513	1483	1391	1330	1361	1712	9051	17451	5561	2453	1987	46524
1933	1942	1590	1368	1452	1239	1330	1849	4339	13938	4018	2331	1972	37268
1934	1595	1479	1478	1506	1322	1502	2725	4913	3040	1735	1331	964	23640
1935	1170	1010	708	599	637	764	1100	6590	13910	7230	2520	1470	37708
1936	1310	1100	1060	837	690	906	3900	7270	5280	1380	1530	1260	27023
1937	1300	1130	1030	891	696	873	1240	8460	9430	3280	1570	1430	31330
1938	1350	1040	861	899	742	980	2100	8170	10930	3980	2260	1520	34892
1939	1730	1460	1350	1170	833	1070	2570	8590	7770	4710	2080	1650	35033
1940	1470	1110	1020	1120	750	841	1870	10440	12020	4160	2070	1680	38551
1941	1610	1170	1070	1270	1050	1220	1900	6790	7370	2780	1920	3430	31490
1942	3260	2070	1900	1510	1010	1230	4050	7340	10830	8040	2740	1960	45940
1943	1830	1590	1270	1200	1150	1060	4050	7770	14190	8260	2820	1960	47050
1944	1930	1740	1260	1120	1100	1060	1300	8060	13970	7630	2750	2670	44490
1945	2300	1500	1170	1100	1100	1020	1230	8330	11990	9250	2780	2180	44000
1946	2080	1790	1610	1410	1410	1480	4680	6920	9200	5510	2950	2290	41430
1947	2060	1900	1370	1040	916	994	2230	12640	14280	9860	3760	3310	54410
1948	2780	1940	1860	1810	1060	1480	7290	17860	15830	6390	4590	3030	65920
1949	2510	2230	1840	1210	1250	920	3120	8710	9830	4180	2130	2170	40100
1950	2030	1510	1390	1120	1160	1160	1810	6090	12170	7680	3380	2330	41830
1951	2060	1810	1740	1500	992	653	3150	10450	6850	5260	2610	2080	33155
1952	2050	1360	1220	1570	1060	1120	3960	12460	14140	5850	2970	1980	49740
1953	1630	1251	1260	1165	1455	1093	1930	5650	13500	7570	2370	2000	40930
1954	1850	1480	1543	399	1295	1575	2050	7380	10620	6320	2940	1630	40692
1955	1340	1149	1631	1298	1021	1039	1231	8190	13420	6150	2630	1440	40539
1956	1720	1128	1373	1150	873	1159	2760	7070	11920	3290	1950	1860	36253
1957	1730	1392	1330	979	910	1155	1400	7320	15670	5660	2190	1950	41686
1958	1710	1350	1320	1290	1083	1121	2010	11900	9040	4490	2620	1790	39724
1959	1550	1470	1320	1270	935	1150	2360	9290	19830	8990	2940	2560	53665
1960	2640	2110	1570	1330	1310	1480	3490	7470	13820	5940	2910	1760	45830
1961	1530	1400	993	707	1014	1155	1810	6960	9450	2330	1750	1880	30979
1962	2790	1630	1230	1123	1099	1270	4840	9390	12160	7210	3690	2490	48962
1963	2200	1053	1860	1180	1307	1490	2740	11760	13930	5890	2960	2130	48500
1964	1800	1400	935	710	738	929	2770	11590	15720	10050	3760	2530	53032
1965	2280	1510	2140	1590	1310	1580	2380	10780	19430	13150	4240	3490	63830
1966	2701	2108	1671	1430	1293	1379	2440	11430	10630	5400	3120	1940	45512
1967	2050	1370	1563	1226	1041	1275	1510	10450	18100	10050	3040	2160	53835
1968	2540	2130	1840	1650	1360	1610	1930	11390	19680	13030	6230	4550	66940
1969	3980	2140	1600	1770	1221	1590	4710	17910	14750	10340	3400	2680	66101
1970	2430	1540	1690	1410	1480	1490	1330	17730	25240	11750	4450	3560	74250
1971	3080	2270	1560	1405	1580	1560	2130	12980	18590	11340	4620	3340	65035
1972	2930	1980	1376	1371	1342	2080	2530	9010	12840	5380	2080	2290	45709
1973	2310	1680	1280	972	967	1655	1268	13500	15360	7310	2670	2780	51752
1974	2190	2150	1450	1740	1174	1180	2930	10300	23330	10240	3470	2710	62994
1975	2200	1650	1250	1630	1470	1700	1320	5620	22010	17480	3840	3150	63320
1976	2980	2530	2130	1790	1650	1670	3260	15350	13970	9520	3650	2910	61610
1977	2790	1780	1500	1323	1272	1716	4110	8900	10420	3650	2240	2030	41729
1978	2970	1730	1630	1430	1310	1760	3820	11910	12230	9520	3360	3420	55130
1979	2560	2040	1500	1440	1130	1540	2230	9770	14110	6290	3150	2280	48150
1980	1620	1520	1310	1250	1150	1410	3890	11840	10090	4520	2230	1980	42790
1981	2110	1700	1430	1410	1074	1300	3100	15730	16070	6300	2430	2430	55144
1982	2270	1660	1910	1010	1240	1240	2280	9040	16050	10350	3770	3270	54090
MEAN	2124	1620	1441	1264	1138	1283	2636	9737	13338	6344	2878	2295	46708
S.D.	594	371	305	283	237	297	1205	3220	4376	3258	926	720	11374
DEF. VAR.	.279	.229	.212	.223	.208	.230	.457	.330	.328	.469	.321	.313	.243
ERCENT OF NNUAL MEAN	4.5%	3.5%	3.1%	2.7%	2.4%	2.8%	5.6%	20.8%	28.6%	14.9%	6.2%	4.9%	
UM OF MONTHLY MEANS													46,708.5

WATER RIGHTS

Storage rights held by the State of Montana in Hyalite Reservoir are junior to over 97% of the claimed direct flow rights in the basin. Except for May and June, inflows to the reservoir normally are released to meet the demands of the senior direct flow rights. Storage occasionally occurs in other months during brief storm runoff periods.

In most years direct flows diminish to levels below the agricultural demands about mid-July. Holders of contracts for stored water then request releases from Hyalite Reservoir. The Middle Creek Water Users Association has the responsibility of regulating these flows from storage. In critically dry years, it often becomes necessary for the district court to appoint a water commissioner to regulate diversions from Middle Creek to direct flow and storage contract holders.

A new water right permit for enlarging the project has been applied for. The exercise of water rights prior to those applied for in the new permit, particularly those held by the U.S. Bureau of Reclamation is presently the subject of a lawsuit. The State is currently meeting with the U.S. Bureau of Reclamation to discuss the means whereby the DNRC would obtain water for the proposed project expansion if the Federal government prevails in this lawsuit.

Direct Flows

The Montana State Engineer in 1953 reported numerous water rights on Hyalite Creek and its tributaries (State Engineers Office, 1953). Two decrees (42 rights) and 67 filed appropriations of water were reported. These total over 740 cfs which exceeds the peak flow of record. It is obvious that this overstates actual usage since surplus flows are known to exist.

According to state law, failure to claim all non-decreed water rights means abandonment of a right. The procedure adopted herein to quantify agricultural demands utilizes recent SB76 water rights claims.

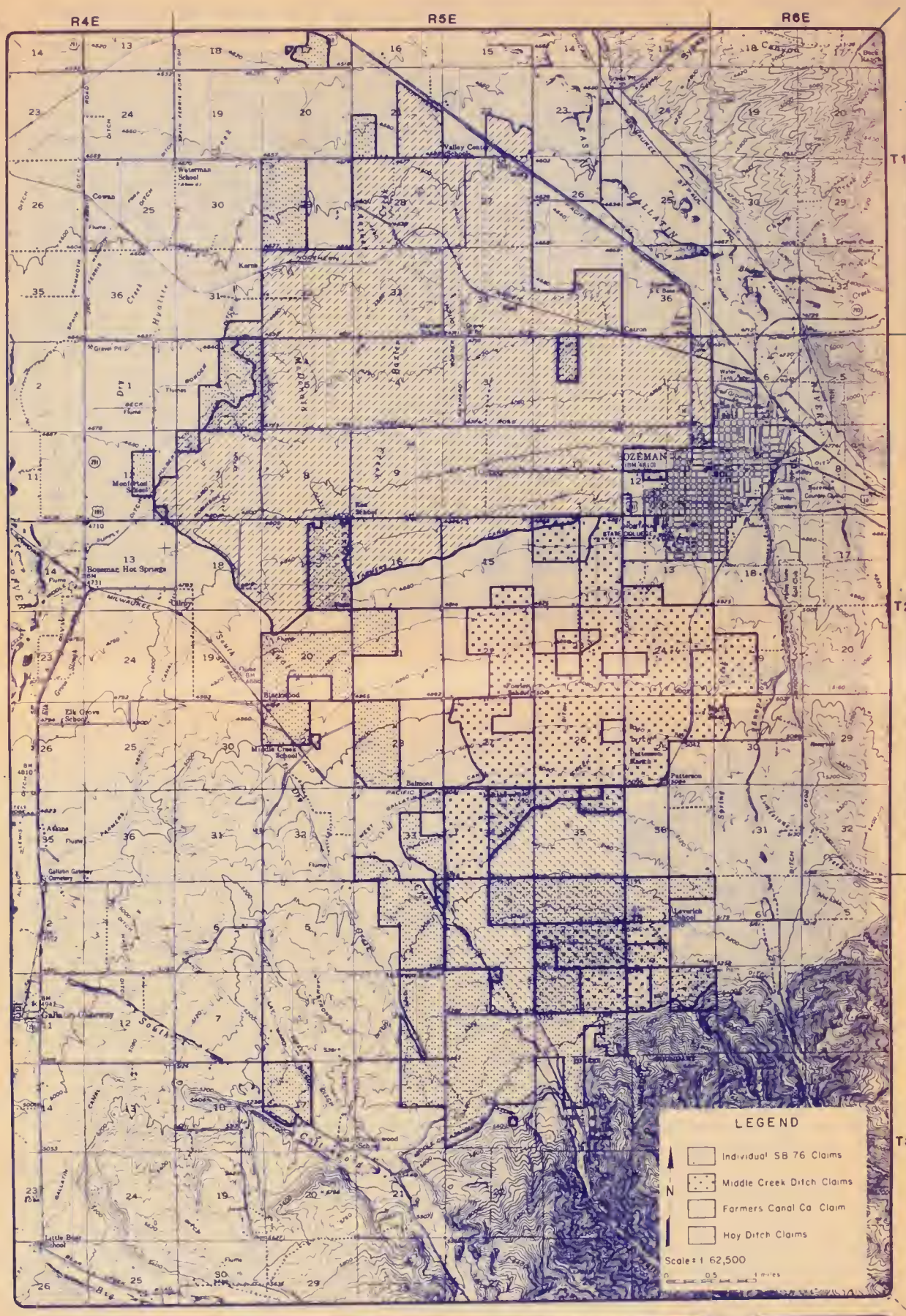
Senate Bill (SB)76 claims. SB76 claims of record were obtained (Montana Water Rights Bureau, 1983). Irrigation claims were plotted on a legal land description base map according to the claimed service area description. Several overlaps were noted. (See Figure IV.1.) An additional procedure as described in the following section was used to eliminate these duplications.

Direct Flow Irrigation. Several sources were used to determine the best description of direct flow irrigation area. The SB76 claims (Montana Water Rights Bureau, 1983), Montana Water Resources Survey (State Engineers Office, 1953) and aerial photography (ASCS, 1979; ASCS, 1980) were used to determine under which ditch or subarea each acre was served. See Figure IV.2 for the results of this determination. A total of 24,819 acres were identified as being served by direct flow rights from Hyalite Creek. A breakdown of this acreage by ditch or subarea is shown on Table III.4.

DNRC Water Right Claims

Water right claims made by the state for the Middle Creek Dam project were made as a part of the SB76 claims process (Montana Water Rights Bureau, 1983). The Engineering Bureau of DNRC claim a priority date of July 12, 1938 for the following appropriations:

- Irrigation 92,000 cfs maximum diversion rate
  73,047 AF maximum annual volume
  30,420 acres of irrigation



MIDDLE CREEK DAM REHABILITATION

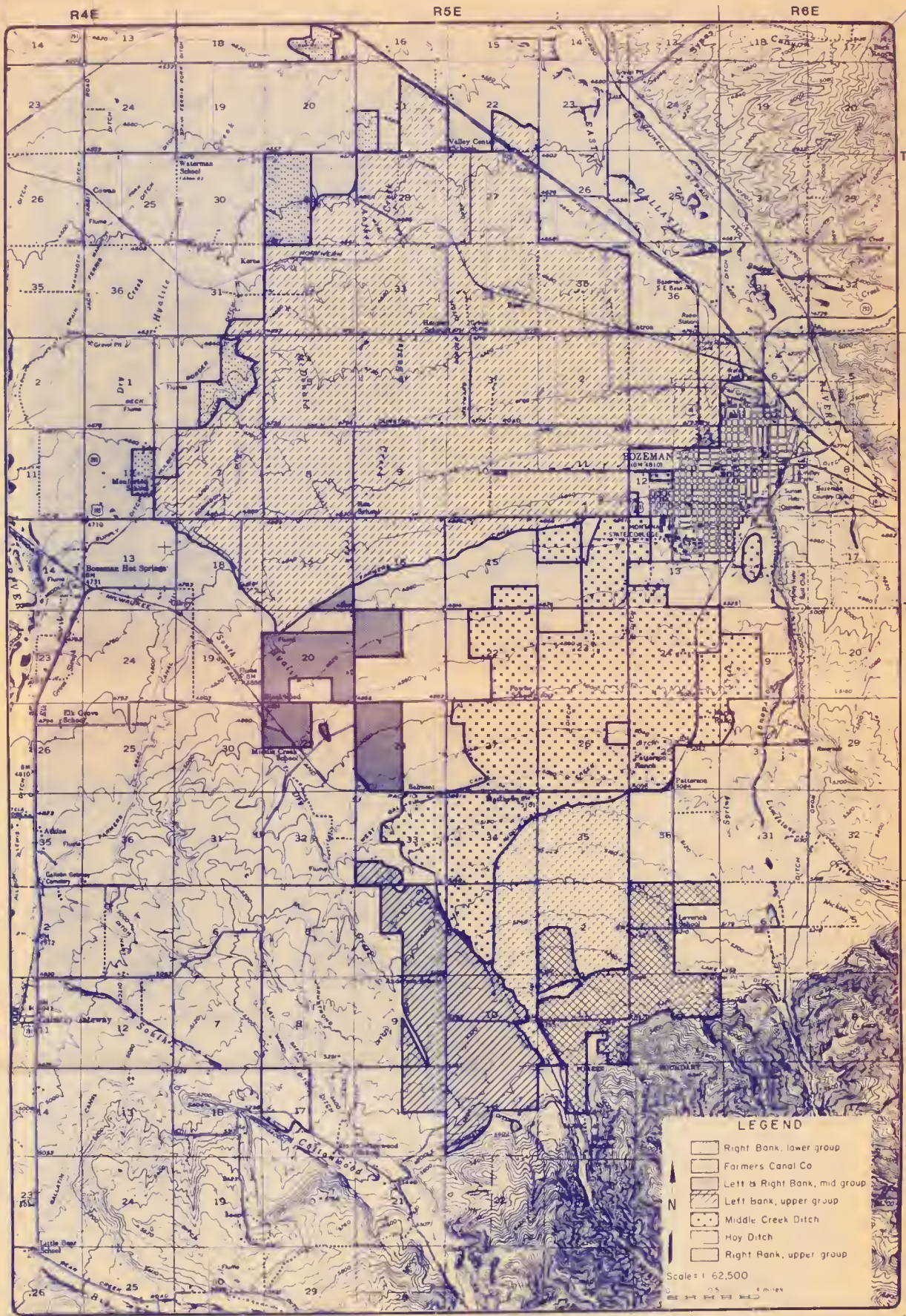
HYALITE CREEK S.B. 76 WATER RIGHT CLAIMS

SEPTEMBER 1984

8M087.113

FIGURE IV.1

HKM ASSOCIATES
ENGINEERS-PLANNERS



MIDDLE CREEK DAM REHABILITATION

HYALITE CREEK DIRECT FLOW IRRIGATION

SEPTEMBER 1984

8M087.113

FIGURE IV.2

HKM ASSOCIATES
ENGINEERS PLANNERS

- Stockwater — 30 cfs maximum rate; 376 AF maximum annual volume; 11,400 animal-units
- Industrial Storage (Municipal) — 92,000 cfs maximum diversion rate; 8,027 AF maximum annual volume
- Industrial Use (Municipal) — 15 cfs maximum diversion rate; 2,000 AF maximum annual volume

Storage Contracts

Three-party contracts for delivery of storage water at the dam of 7,810 AF have been entered into by the state, the Middle Creek Water Users Association, and the individual users. These contracts do not specify the land to which storage water is to be applied. The state has defined an area in which its SB76 claims are to be applied. Additional specificity is required for the purposes of this investigation and loan application to the USBR.

The storage service area shown in Figure III.3 was delineated by using the current contract purchasers (as of 5-24-83) noted in Appendix C, ownerships recorded at the courthouse (Gallatin County Courthouse, 1983) and the Gallatin County ASCS office (ASCS, 1983), and a telephone survey. Ninety-seven percent of the ownerships were determined through this process. The potential service area based on ownership is plotted on Figure III.3 and divided by canal or subarea in Table III.4. A total of 14,912 acres of ownership were identified. It is assumed that 240 acres (or 60%) of each typical 400-acre farm unit are irrigated. Therefore, it is assumed that 8,947 acres of land can be served by Middle Creek storage at the present time.

WATER UTILIZATION

A 10-foot increase in dam height is proposed to accommodate the auxiliary spillway construction and provide additional storage for M & I use. Correspondingly, 10.2 feet is proposed to be added to the existing normal pool level. This increase in spillway elevation will increase the active storage pool by 2,334 AF. It should be noted that flashboards have historically been in place over the crest of the existing spillway. These flashboards are 2 feet in height and have increased storage by 417 AF. This increment of storage has not been marketed. Since the flashboards should not be in place to accommodate a flood, the flashboards were not considered in the water utilization or hydraulic analysis. However, the additional storage is considered in the water rights, historical operation and environmental analysis. If the flashboards are considered, the actual increase in the water surface elevation is 8.2 feet instead of 10.2 feet.

To evaluate the potential for developing additional storage in Hyalite Reservoir, it was necessary to gain an understanding of water utilization in the basin. Conclusions are based primarily on historic records (available for 1952 only), discussions with people familiar with the system, and published data for the area. Since new storage would take place during the high runoff period, only the months of May and June were studied.

Models

Two models were used to evaluate water utilization for Middle Creek Dam. The first model was developed by HKM Associates to estimate storable flow for the study period of 1931-1982. The second model was the U.S. Army Corps of Engineers HEC-3

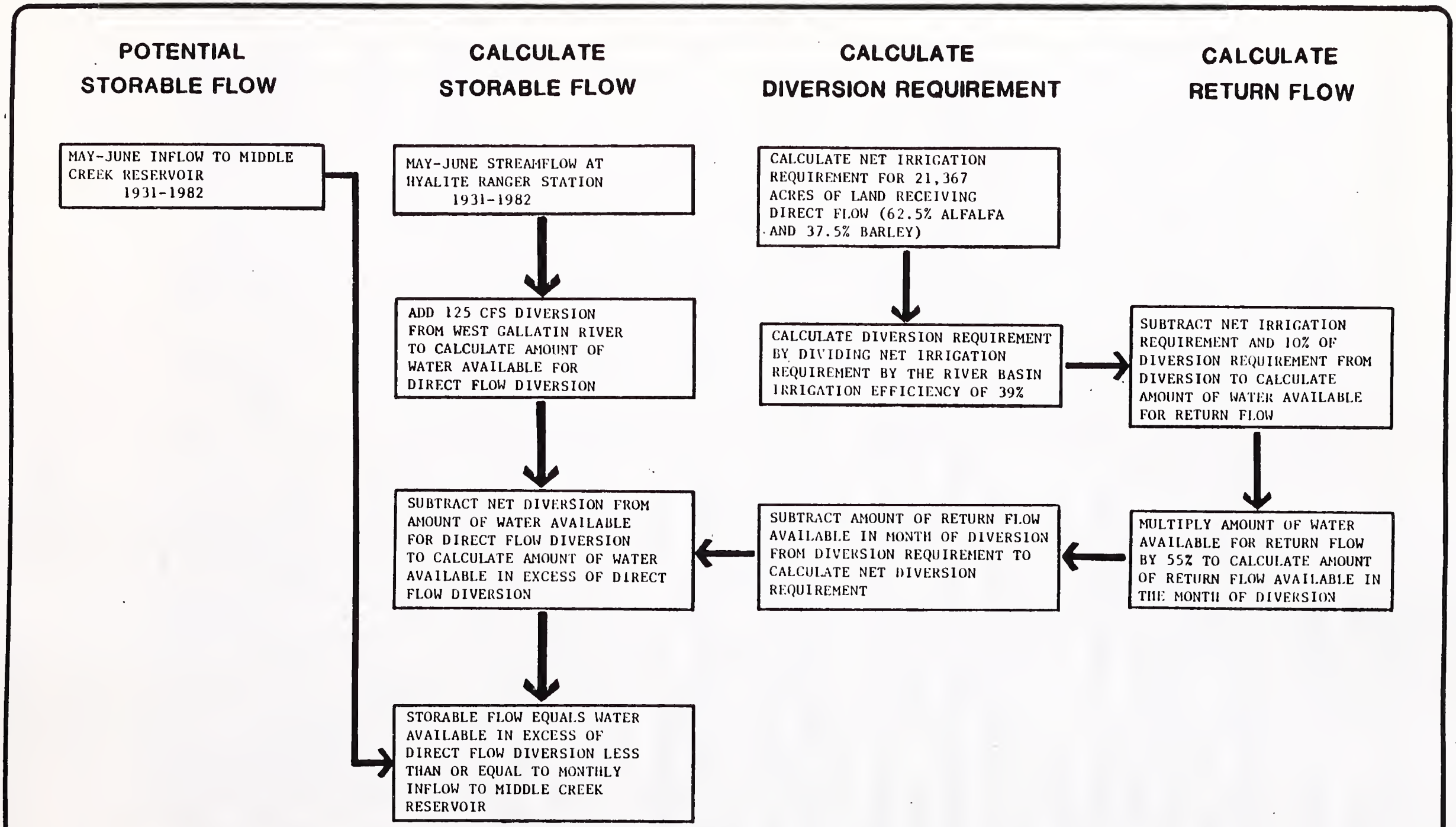
computer program, Reservoir System Analysis for Conservation (COE, 1981), which was used to evaluate the difference in reservoir operation between historic and proposed conditions.

Storable Flow Model. The storable flow model was developed by HKM Associates and is presented in Figure IV.3. The logic of the model is based primarily on data available for 1952. The year 1952 was selected because USGS streamflow measurements for Hyalite Creek at Belgrade are available for this year only (USGS, 1983).

The study period for this model is 1931-1982 as described in the report Hydrologic Potential For The Hyalite Creek Watershed (HKM, 1983). Since new storage would take place in the high runoff period, only the months of May and June were studied.

The storable flow model was calibrated for the year 1952 in which the most data is available. Since the net irrigation requirement for May 1952 was zero, only June 1952 was evaluated. Information available for the Hyalite Creek Basin is presented below:

1. USGS streamflows for Hyalite Creek at Hyalite Creek Ranger Station (USGS, 1983).
2. USGS streamflows for Hyalite Creek at Belgrade (USGS, 1983).
3. Approximately 60 percent of lands in the service area (Figure III.1) and all lands receiving direct flow outside of the service area (Figure IV.2) are being irrigated. These lands cover 21,367 acres.
4. The cropping pattern for these 21,367 acres consists of 62.5% alfalfa, and 37.5% barley.
5. Approximately 125 cfs is available through the Farmers Canal from the West Gallatin River. This is based on a review of water rights (Montana Water Rights Bureau, 1983) and discussions with water users in the basin.



MIDDLE CREEK DAM REHABILITATION

STORABLE FLOW DIAGRAM

8M087.113

SEPTEMBER 1984

FIGURE IV. 3

HKM ASSOCIATES
ENGINEERS — PLANNERS

6. Demand for the City of Bozeman in 1952 was approximately 4 cfs in June of 1952. This is based on information from the City of Bozeman that indicates current demand can approach 9 cfs in a dry year and demand in 1952 was approximately half of current demand.

The following conclusions were drawn based on the June 1952 calibration:

1. River basin irrigation efficiency is approximately 39%. This efficiency reflects primarily flood irrigation which was prevalent in the 1950's.
2. Return flow equal to approximately 55% of the amount of water available for return flow in the month.
3. Nonbeneficial consumptive use in the basin is approximately 10% of the water diverted but not consumptively used by the crops.
4. The net irrigation requirement for June 1952 was 3.4 inches as compared to the 1931-1982 average and maximum values of 2.0 and 5.5 inches, respectively. Since the system experienced above average demand in June 1952, these conclusions are conservatively representative of other years during the period 1931-1982.
5. These conclusions relative to June are appropriate for May also.

The calibrated storable flow model was then used to generate May and June storable flows for the period 1931-1982. To determine how much of the storable flow would be available for storage in the enlarged portion of the pool, it was necessary to estimate the probable pool volume on April 30 preceding the months of May and June when storage would take place. April 30 storage records for the period 1952-1982 were reduced by 1,140 AF to reflect the amount of winter diversion granted the City

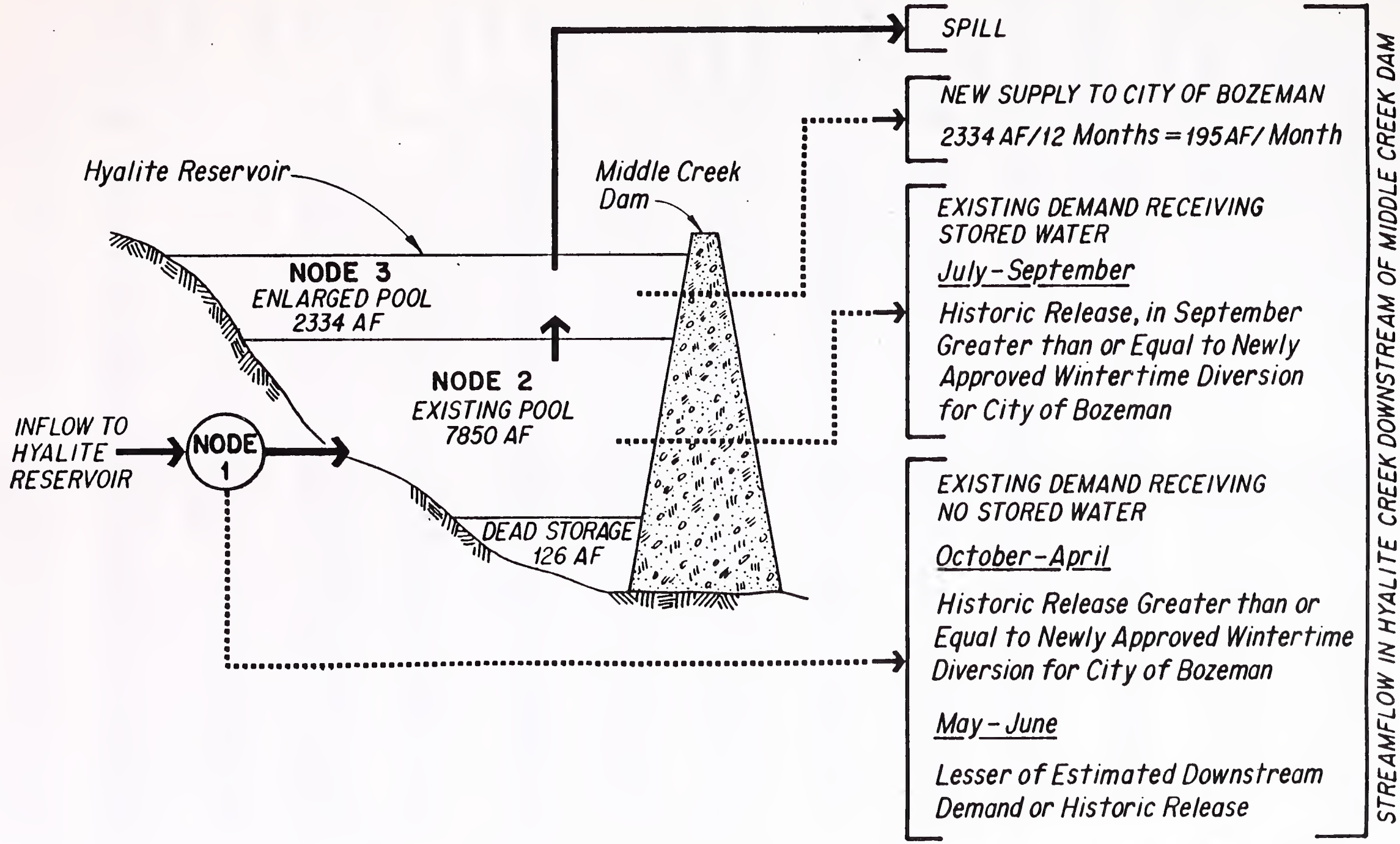
of Bozeman by DNRC in 1984. A statistical analysis of the April 30 storage records indicates a pool volume of at least 2,280 AF can be anticipated in 90 of 100 years. The computed storable flow for May and June was added to the assumed April 30 storage of 2,280 AF. The results indicate that the entire enlarged reservoir pool of 2,334 AF could be filled during May and June in 91 of 100 years. In the remaining 9 of 100 years no storable flow is available to the enlarged portion of the reservoir. However, in 8 of the 9 years without storable flow carryover, storage of 389 AF is possible. These 8 years were preceded by years in which there was storable flow in excess of space available in the reservoir. Therefore, the 389 AF[1/] that would have been released to the City of Bozeman in May and June could be served with direct flow and 389 AF could be carried over in storage to the following year.

HEC-3 Model. The U.S. Army Corps of Engineers Model, Reservoir System Analysis for Conservation (COE, 1981), was used to evaluate the difference in reservoir operation between historic and proposed operation. A diagram of the HEC-3 model is presented in Figure IV.4. The HEC-3 model was operated for the period 1952-1982 when historic reservoir pool volume were available (see Table IV.10).

The following changes were made to the historic release schedule of the reservoir to reflect proposed conditions:

1. An additional 2,334 AF of storage was added (10.2 feet increase in normal pool level).
2. A demand of 195 AF/month (2,334 AF/12 months) was added to reflect future demand of the City of Bozeman on this storage.

1/ The additional 2,334 AF that would be stored in the enlarged portion of Middle Creek Reservoir would be released in 12 equal parts (i.e. 2,334 / 12 = 195 AF). The amount released in May and June would be (2 / 12) x 2,334 AF = 389 AF.



MIDDLE CREEK DAM REHABILITATION

HEC-3 MODEL DIAGRAM

8M087.113

SEPTEMBER 1984

FIGURE IV.4

HKM ASSOCIATES

Table IV.10

HISTORIC END-OF-MONTH STORAGE

FILE -- 0604950A
SITE -- MIDDLE CREEK RESERVOIR
UNIT -- AC-FT
NOTE -- ANY MONTH WITH ####### INDICATES NO DATA AVAILABLE

02/13/85

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL MEAN
1952	2520	2270	2120	2600	2600	2570	3290	4470	5270	4760	3730	2940	3261
1953	2820	3190	3750	4100	4710	4980	5480	5680	5440	4470	1490	1150	3937
1954	1240	1640	2320	2640	3300	4250	4760	6440	6520	5200	2470	2420	3600
1955	2410	2600	3430	4230	4710	5190	5640	5940	6540	5530	2100	1730	4170
1956	1690	1820	2560	3030	3350	3670	4510	5760	6180	3420	1320	1150	3205
1957	1170	1870	2450	2840	3110	3430	3700	5840	7660	6700	3620	3480	3822
1958	3420	3440	3470	3490	3690	3960	4520	7660	7660	6700	4470	3790	4688
1959	3370	3670	3930	4160	4200	4310	4890	6880	7660	6880	3600	3420	4747
1960	3540	3540	3770	3960	4220	4430	5350	6880	7860	5000	2400	1920	4405
1961	1970	2350	2870	3190	3490	3830	4520	7470	7200	3490	1640	1370	3615
1962	1530	1730	1980	2300	2510	2720	4400	7270	7920	7920	5300	4540	4176
1963	4060	4130	4140	4320	4730	5140	5280	8030	7970	5910	3000	2360	4922
1964	2470	2670	2770	2890	3010	3290	5050	7170	7970	6890	3360	2890	4202
1965	3000	3110	3460	3760	3930	3990	4130	5130	7790	7470	4610	1160	4295
1966	391	819	1170	1360	1780	2350	3290	8240	7970	4840	2150	1560	2993
1967	1150	1360	2060	2600	3000	3480	3920	6620	7990	7580	3670	2740	3847
1968	3060	3100	3120	3340	3330	3360	3470	6880	7970	7620	6000	5400	4720
1969	4450	2900	2970	3480	3800	4030	5180	7820	8080	7330	4250	3470	4813
1970	3150	3140	3370	3770	4100	4400	4430	5400	7860	7350	4950	3700	4635
1971	3150	2970	3410	3990	4510	4820	3840	5010	7720	6940	3370	2570	4358
1972	2320	2350	2730	3310	3740	4280	4880	7760	8040	6960	3210	2490	4339
1973	2400	2450	2500	2540	3030	4160	4620	7390	7970	5840	3530	2750	4098
1974	2900	2980	3210	3910	4360	4400	4200	4470	7470	6840	5360	4720	4568
1975	3170	3210	3110	3570	3880	4230	3400	3340	7020	7600	4470	3360	4196
1976	2850	2750	3310	3650	3870	4070	4560	6360	7800	6670	4080	3480	4454
1977	2970	2520	2700	3150	3690	4690	6740	7890	7960	6180	3170	2950	4550
1978	2970	2970	3310	3650	3930	4240	4570	7170	7920	7640	5010	4180	4796
1979	3530	3310	3310	3470	3440	3730	3780	7350	7990	6100	3820	3170	4416
1980	2740	2710	2790	2950	3170	3530	4390	7360	8030	6530	4070	3520	4324
1981	3310	3300	3460	3770	4070	4370	5320	7560	7850	6240	3540	2910	4641
1982	2890	2950	3660	3560	3800	3820	4160	6550	7660	7760	5690	4400	4741
MEAN	2664	2703	3006	3341	3646	3990	4524	6573	7514	6334	3659	2960	4263
S.D.	898	723	652	658	683	688	772	1205	751	1230	1220	1095	501
COEF. VAR.	.337	.267	.217	.197	.187	.172	.170	.183	.099	.194	.333	.369	.118
PERCENT OF ANNUAL MEAN	5.2%	5.3%	5.9%	6.6%	7.2%	7.8%	8.9%	12.9%	14.8%	12.4%	7.2%	5.8%	

SUM OF MONTHLY MEANS 50,921.9

3. September - April flows reflect the increase in direct flow demand to the City of Bozeman approved during 1984.
4. May - June flows were limited to the estimated downstream direct flow requirement (see Storage Flow Model section).

A table of end-of-month reservoir pool volumes is presented in Table IV.11.

WATER QUALITY

Hyalite Creek has good quality water at the monitoring site located at the parking loop near the Middle Creek ditch diversion and a short distance below the USGS stream gaging station. It appears that the water met the former A-Open (now named A-1) Montana Water Quality Standards for the parameters analyzed on the sample dates.

Recorded water temperatures have been 60°F or less, turbidity averages 4.4 NTU (range 0 to 43 NTU), specific conductance averages 122 micromhos (range 62 to 210), pH is about eight units (range 7.1 to 8.6) and alkalinity averages 61 milligrams per liter (mg/l). Nitrate nitrogen (as N) averages 0.02 mg/l (range .00 to .13) and phosphate phosphorus (as P) averages .06 mg/l (range .04 to .12) which indicated management activities have had no effect on stream nutrients and also that algae blooms should not occur.

Suspended sediment concentrations average 11 mg/l (range 1 to 51) and sediment yields average 6.2 tons per day (range 0.3 to 32). These are considered to be low amounts, especially since some of the most erosive soils are located below the reservoir.

The water is considered to be soft (hardness under 75 to 150 mg/l) during fall-winter months. Sodium concentrations are very low, averaging only 2.5 mg/l (range 1.1 to 5.2 mg/l).

Table IV.11

FUTURE END-OF-MONTH CONTENTS

FILE -- EOMFUT3
SITE -- MIDDLE CREEK RESERVOIR
UNIT -- AF
NOTE -- ANY MONTH WITH ####### INDICATES NO DATA AVAILABLE

02/28/85

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL MEAN
1952	4229	4036	3839	4124	3929	3734	4259	8071	10310	9605	8380	7395	5992
1953	7200	7274	7355	7360	7600	7551	7856	9402	10310	9145	5950	5435	7704
1954	5330	5535	5845	5650	5759	6096	6411	8967	10310	8795	5870	5625	6674
1955	5430	5421	5803	5915	5903	5705	5859	8663	10310	9105	5430	4915	6534
1956	4720	4655	4826	4321	4626	4526	5271	8446	10310	7355	5060	4695	5734
1957	4520	4703	4848	4702	4507	4503	4578	8139	10310	9155	5880	5545	5953
1958	5350	5175	5010	4935	4774	4743	5108	8385	10310	9155	5730	5955	6295
1959	5650	5765	5830	5365	5684	5593	5934	8709	10310	9335	5800	5485	6673
1960	5410	5215	5250	5245	5310	5325	6050	8734	10310	7255	4460	3785	6029
1961	3640	3825	3691	3496	3379	3375	3870	8319	8124	4266	2416	2145	4212
1962	2306	2506	2756	2922	3068	3273	4958	8330	10310	10115	7300	6345	5349
1963	6150	6025	5840	5925	5944	6159	6104	8754	10310	8055	4950	4115	6519
1964	4030	4035	3894	3699	3504	3318	4716	8240	10310	9035	5310	4545	5394
1965	4560	4475	4630	4735	4710	4575	4520	9163	10310	9795	5740	3395	5859
1966	2900	3133	3239	3284	3392	3570	4315	8092	10310	6985	4100	3315	4723
1967	3120	3135	3462	3517	3422	3516	3761	7387	10310	9705	5600	4475	5159
1968	4600	4445	4270	4295	4100	3935	3850	7920	10310	9765	7950	7155	6049
1969	6960	6765	6640	6955	7035	7040	7935	9453	10310	9365	6090	5115	7474
1970	4920	4725	4760	4963	5098	5203	5038	8359	10310	9641	7046	5601	6305
1971	5406	5211	5456	5655	5980	6095	5900	8673	10310	9335	5570	4575	6514
1972	4380	4215	4390	4561	4709	5054	5459	8515	10310	9035	5090	4175	5824
1973	3930	3835	3690	3535	3379	3780	3964	7962	10310	7985	5450	4505	5200
1974	4460	4345	4380	4850	4862	4707	4512	8165	10310	9485	7810	6975	6239
1975	6730	6625	6430	6695	6810	6965	6770	9000	10310	10310	6935	5680	7406
1976	5485	5290	5635	5800	5811	5796	6091	8749	10310	8985	6200	5405	6631
1977	5210	5015	5000	5017	4851	4656	6006	8718	10310	8335	5130	4715	6030
1978	4540	4345	4490	4624	4709	4824	4959	8339	10310	9835	7010	5985	6153
1979	5790	5595	5400	5365	5170	5265	5120	8390	10310	8225	5750	4905	6273
1980	4710	4515	4400	4365	4330	4497	5152	8405	10310	8615	5950	5315	5837
1981	5120	4925	4890	5005	4903	4915	5670	8593	10310	8505	5610	4785	6102
1982	4590	4455	4622	4427	4472	4297	4442	8139	10310	10215	7950	6465	6193
MEAN	4886	4813	4859	4906	4892	4925	5308	8472	10239	8954	5991	5104	5104
S.D.	1100	1051	1031	1065	1120	1130	1070	384	392	1200	1244	1160	739
COEF. VAR.	.225	.218	.212	.217	.229	.229	.201	.045	.038	.135	.207	.227	.121
PERCENT OF ANNUAL MEAN	6.7%	6.6%	6.6%	6.7%	6.7%	6.7%	7.2%	11.6%	14.0%	12.1%	8.2%	7.0%	

SUM OF MONTHLY MEANS 73,254.4

Bacteria samples collected by Montana State University researchers in 1973 show geometric means of two fecal coliforms and two fecal streptococcus bacteria per 100 ml. Results in 1974 were the same. These are very low levels and it appears that Montana's A-1 fecal coliform standard of 50 bacteria per 100 ml. as a geometric mean has been easily met.

CHAPTER V
DRAINAGE

GEOLOGY AND WATER TABLE

The service area of Middle Creek Reservoir lies on Quaternary alluvial fan deposits that extend from the Gallatin Mountain foothills north, approximately to Interstate Highway 94. These deposits are deep to bedrock, with more than 100 feet of coarse alluvial materials over bedrock in places. The fan material is in turn overlain by a mantle of loess.

The Bozeman fan is recharged by snowmelt, numerous mountain streams that lose all or most of their flow into the fans, and losses from irrigation. It has been estimated by the U.S. Geological Survey (Hackett, et. al., 1960) that at least half of the irrigation water applied is added to the water table through deep percolation.

The massive primarily natural recharge into this fan has resulted in the water table to be within five feet of the surface over much of the area.

IRRIGATION PRACTICES

Irrigation has been practiced on the Bozeman fan for many decades. Experience has shown that certain soil series tend to drain more slowly than others. The Huffine and Larimer series, and some phases of the Bozeman series tend to be relatively poorly drained. Cropping patterns over the years have come to reflect the realities of the soils and water table conditions. Deep rooted crops, such as alfalfa, are not grown on the soils with high water tables.

Lands have historically not passed out of production to any degree because of drainage problems. High water tables or poorly drained soils are seldom so serious to preclude shallow rooted crops such as grass pasture and small grains, and cropping patterns have been adjusted accordingly.

DRAINAGE CONSIDERATIONS

While much of the Bozeman fan has a water table within five feet of the surface, the massive, natural recharge would render all but the most localized drainage system practically impossible from an economic standpoint.

The problem has been essentially solved by the operators, in a cost effective manner, by adjusting their cropping patterns. Utilization of the poorer drained areas for pasture is valid in an area that is climatically limited to relatively low value crops and which is heavily dependent upon livestock enterprises. HKM proposes no new cropping pattern for the service area, but instead would continue the practices that have been historically successful.

In summary, while all lands are not suitable for deep rooted crops, artificial drainage of these lands would be most difficult and probably not economically justifiable.

CHAPTER VI
PLAN OF DEVELOPMENT

PHYSICAL PLAN

The selection of a plan for Rehabilitation of Middle Creek Dam was dictated by the requirement that the structure have the capacity to pass the Probable Maximum Flood (PMF) without failure. Although the dam would not fail, the auxiliary spillway system may experience considerable damage. Since the rest of the creek channel would experience similar damage and the frequency of risk of this level of flooding is very low, damage in the auxiliary spillway is considered acceptable.

The more frequently occurring floods must be passed without damage through a principal spillway system designed for this purpose. The 500-year flood was chosen for the design flowrate of the principal spillway system. This frequency of flooding was chosen in lieu of the more commonly accepted 100-year frequency for the following reasons:

1. This choice greatly reduces the chance that the auxiliary spillway will operate with its associated damage.

2. The existing spillway will accommodate the 500-year flood with very little modification and the additional cost of the lower drop structure is not significantly increased.

3. The difference between the 100-year flood (700 cfs) and the 500-year flood (1,000 cfs) is not significant.

4. The margin of safety provided will encourage the MCWUA to regulate the outlet works to insure that the reservoir fills each spring.

These criteria led to a design incorporating two major features. The first feature includes the excavation of a large auxiliary spillway on the left (west) abutment. The excavated material will be placed on top of the dam embankment, raising the crest elevation by 10 feet and providing the necessary freeboard during the PMF. In addition, the storage of the reservoir will be increased by 2,334 AF which can be utilized for irrigation and municipal use. The second feature of the physical plan is the rehabilitation of the existing principal spillway to provide adequate hydraulic capacity for passing the 500-year flood without significant damage. The major features are shown in the site plan (Exhibit No. A-1) found in Appendix A.

GEOTECHNICAL INVESTIGATION

A field drilling program and geotechnical investigation was conducted during the fall and winter of 1983. The details of this study are reported in Middle Creek Dam, Geotechnical Investigation (HKM, 1984b) and the results are summarized in the following paragraphs.

The purpose of this geotechnical investigation was to provide an understanding of the physical conditions on which to evaluate rehabilitation alternatives for this facility.

"As-built" drawings of the project are not available. Design drawings are on file at the DNRC in Helena, Montana (DNRC, 1983). There was no stability analysis of the embankment previous to this investigation. No instrumentation, such as piezometers and survey control points, had been established at the facility prior to this study.

General Approach

The general approach began with a subsurface soils investigation to determine the physical and engineering properties of the materials. Subsequently, representative soil samples were selected for laboratory testing and engineering analyses were performed. The findings of these field and laboratory investigations and engineering analyses were used as the basis for rehabilitation alternative selection and evaluation.

The field investigation included making 15 exploration drill holes and 4 test pits to determine soil conditions and obtain samples for laboratory testing. Instrumentation, to monitor embankment movements and changes in ground water levels, was installed during the field investigation. A geologic investigation was made to assist in evaluating the soils and the impact of a seismic event on the structure. The engineering analyses included seepage and stability studies. Both static and dynamic stability analyses were also performed.

Findings of Condition of Existing Dam

As recommended in the Phase I Inspection Report (COE, 1980), stability of the existing structure was analyzed. The results of this investigation are reported in detail in the Middle Creek Dam Geotechnical Investigation Report (HKM, 1984b). The analysis of the enlarged dam can be found in the Design section presented later in this chapter.

Seepage through the left abutment is high but does not create a stability problem with the existing embankment nor a piping problem through the abutment. Presently, this seepage is being at least partially controlled by the existing drains. The

condition of the foundation drain is unknown. An increase in the embankment crest elevation will require preserving and lengthening the existing drain system.

Seepage through the embankment and its foundation and through the right abutment does not appear to be a problem. Ground water levels and seepage throughout the downstream area should continue to be monitored. If the embankment and pool elevations are increased, a monitoring system should be constructed to record the drain discharge. Presently, a critical flow flume has been installed to measure discharge from the left abutment drain. It is recommended that the seepage from both abutments be monitored.

The results of the static stability analysis indicate the factors of safety for the existing structure are within the Recommended Guidelines (COE, 1975). Transition to the results of the dynamic stability analysis indicates that the minimum factor of safety against liquefaction is 1.5. These results are based on a maximum earthquake (design earthquake) of 6.5 (Richter Magnitude) at a distance of 25 kilometers from the dam with a horizontal acceleration of 0.22g at the base of the structure.

Deformation resulting from the design earthquake is calculated to range from 0.4 to 1.0 foot. This amount is relatively small compared to the available freeboard and is not considered a problem.

DESIGN

The project plan has three major features: construction of an earthen auxiliary spillway, raising of the dam structure, and rehabilitation of the existing principal spillway. These actions will allow the dam structure to meet dam safety criteria for passage of probable maximum flood flows while

minimizing the cost of repair and/or facility additions. This has been achieved by using the existing structure wherever possible.

Design Rationale

There were two levels of concern in this preliminary design which influenced the selection of design criteria. First, the principal spillway has been redesigned so that it can accommodate the routed 500-year flood without damage. Secondly, the principal and auxiliary spillways must be capable of safely passing the PMF without overtopping the dam. Use of the PMF was dictated by the large size of the dam and the expected consequences of failure including possible loss of life and the potential for extensive economic losses.

Auxiliary spillway design criteria is dictated by present standards which require that the public safety be insured. These criteria have been set because of dam failures in the past.

Alternatives Considered

In the planning process, many alternatives were considered. The following discussion summarizes the results of these studies out of which the recommended plan evolved.

Three levels of increase in dam height were examined; no increase, a 5-foot increase and a 10-foot increase. The dam height increases allowed better utilization of the natural topography in the left abutment area for an auxiliary spillway. Two alternatives were examined for raising the dam; earth reinforced structure and placing embankment on the downstream side. Earth reinforced structure was chosen on the

basis of lesser cost, reducing loading on the existing embankment (less settlement) and conduit, better performance during earthquake loading and a reduced construction time.

Concerning the auxiliary spillway, two locations were considered; the right abutment in the vicinity of the existing spillway and in a natural drainage in the left abutment. The left abutment was chosen because the natural topography would accommodate large flows without endangering the dam embankment. To contain these same flows in the right abutment would require expensive structural measures and would occupy the same space as the principal spillway.

The configuration of the auxiliary spillway located in the left abutment is dependent upon the height of the dam. The no-increase configuration is shown on the alternative site plan sheet, Exhibit A-2, Appendix A. This spillway is much wider and deeper when compared to the spillway shown on the recommended general site plan, Exhibit A-1, Appendix A (10-foot increase in dam height). In all alternatives a training dike and excavation is necessary in the lower portion of the spillway channel to prevent flood waters from eroding the embankment.

Many alternatives were considered for the principal spillway rehabilitation. The spillway system was analyzed in two locations; the existing structure and a new structure to make the final drop to Hyalite Creek. Alternatives for the existing structure are listed as follows:

1. Demolish the old spillway and replace it with a new structure.

2. Provide a new spillway in a different location such as the right abutment - embankment contact or an "on-dam" structure (would solve both upper and lower problems).

3. Place a new structure within the walls of the existing structure and replace the stilling basin.

4. Automate outlet works releases as the existing conduit has the capacity to pass 500-year flood flows (serves both existing and lower structure design goals).

5. Repair the existing spillway given no increase in dam height to pass 500-year flood flows.

Alternatives considered for the new, final drop structure are listed as follows:

1. Stabilize the natural channel with drop structures constructed of timber, concrete, gabions, rocks or other materials.

2. Direct flows to a concrete chute located just below the dam on the right abutment.

3. Dike off flows to left near end of channel exit to Hyalite Creek and allow channel to erode, eventually armoring the channel with natural rock.

4. Continue operating reservoir at reduced levels to minimize use of the spillway.

The "on-dam" structure concept was discounted without detailed study because of potential problems. If at all possible, placement of the spillway over an embankment should be avoided because of the higher potential for damage and possible failure

due to piping along the outside surface of the concrete structure, settlement of the embankment, the differential response of the embankment and spillway during earthquakes. Automation of the outlet works is an economical solution but is not foolproof as mechanical equipment would be necessary. Demolition of the old spillway structure would be relatively expensive, and a totally new structure would add additional cost. Erosion of the spillway channel is considered unacceptable from an engineering and environmental standpoint. Access, maintenance and cost were considerations for the gabions or similar weir drop structures.

The life of gabions or timber structures is questionable. Given these considerations, the recommended alternative is placing a new structure inside the old spillway for the upper area and diverting flows to a baffled apron drop just downstream of the right abutment for the lower part of the system. The recommended alternatives are discussed in greater detail in the following paragraphs.

The most economical combination of alternatives is a function of dam height. If the dam is not increased in height, the auxiliary spillway must be wider and deeper to pass the PMF with adequate freeboard on the dam. This results in increased excavation and haul to waste which substantially increases costs. Until an earthwork balance is achieved between material excavated and material used in the dam enlargement, there is a significant cost with waste of the excess material. Three dam heights were examined as a part of the feasibility study (HKM, 1985). The economic minimum occurred with a 8- to 9-foot increase in height. A 10-foot increase was chosen as a recommended alternative as: 1) the City of Bozeman will need the additional water, 2) this amount of additional water is available from the watershed, 3) the earth reinforced structure alternative may become questionable with a height greater than

10 feet, and 4) 10 feet is the limit of increase without impacting existing facilities and project costs.

An alternative to optimize environmental conditions was also considered. This plan would not differ physically from the preferred alternative previously stated. However, the water surface in the reservoir would be held at the historical level at the top of flashboards (8,267 AF of active storage). The remaining storage would be flood surcharge (1,917 AF) and would be released as quickly as possible after it was filled. This operational plan would minimize environmental concerns with the increase in water levels. However, this alternative has the serious disadvantage of not providing additional water to finance the dam safety improvements.

Auxiliary Spillway

The proposed auxiliary spillway is located on the left abutment of the dam as shown on Exhibit A-1.

The peak design flow is 29,000 cfs for the auxiliary spillway, which is the maximum auxiliary spillway flow during the routed PMF. Should a PMF occur, channel velocities greater than 23 feet per second (fps) will be experienced. Considerable damage and erosion will occur if this spillway operates, but the damage would be minor compared to that caused by a dam breach.

Velocities across the crest during the PMF approach 10 fps, which can be expected to cause significant erosion. A concrete sill bordered with riprap will be installed on the crest of the auxiliary spillway to limit erosion of the crest.

The auxiliary spillway proposed will have a circular crest (in plan) having a 530-foot arc length and horizontal radius of curvature of 494.5 feet. A 460-foot transition follows, which narrows the channel bottom arc length from 530 to 37 feet on a slope of 4.17%. Beyond the transition to a point immediately beyond the existing main access road, the channel has a bottom

width of 37 feet and a slope of 0.22%. All side slopes perpendicular to the centerline of the auxiliary spillway are 2.5H:1V. Flow from this excavation spills over the existing main access road into the depressed area below. Water than flows through a 130-foot wide excavation until reaching the steep slope down to Hyalite Creek. In addition, a small dike along the right side of the channel keeps water away from the toe of the dam. The main access road to the reservoir follows the auxiliary spillway to the crest, where it branches either left to the dam crest or right to the campground.

The plan and profile for the auxiliary spillway are shown in Exhibits A-1 and A-7. Hydraulic computations are described in Exhibit E.

Dam Enlargement

The storage capacity of Hyalite Reservoir will be increased by enlarging the Middle Creek Dam embankment. To provide additional storage and to pass the Probable Maximum Flood, the crest will be raised approximately 10 feet, to elevation 6,732.0 feet NGVD.

The embankment will be raised using a combination of construction methods consisting of earth reinforced structure and conventional earthfill as detailed on Exhibit A-8. The earth reinforced structure construction method is used on the crest of the existing embankment where the embankment is high. The earth reinforced structure provides the following primary advantages over the conventional earthfill:

- It costs less than the conventional earthfill method.

- The earth reinforced structure adds some weight to existing fill but significantly less than conventional fill. This

is an advantage because it will reduce additional settlement.

- The earth reinforced structure technique requires less fill. It allows a balance between the cut and fill volumes.

- The earth reinforced structure construction can be completed in one construction season.

The volume of excavation from the auxiliary spillway is 83,800 CY, a portion of which will be used to raise the dam crest elevation to 6,732.0 feet NGVD through the use of both earth reinforced structure and conventional fill. The earth reinforced structure portion will require approximately 16,000 CY fill to provide a crest elevation of 6,732.0 feet NGVD. The conventional fill portion of the dam crest will be at elevation 6,732.2 feet NGVD and will require 30,000 CY with the parking lot on the east end. The dam crest elevation selected will provide 2.1 feet of the freeboard on the earth reinforced concrete portion and 2.3 feet of freeboard on the conventional fill portion at the maximum water surface elevation during the PMF. The additional 0.2 feet of freeboard on the conventional fill portion is necessary to accommodate wave runup, which is not a factor on the vertical face of the earth reinforced structure section with a wave deflector. Besides the dam fill, the training dike at the downstream end of the auxiliary spillway requires 4,600 CY of additional borrow material. Approximately 2,000 CY will be used to reclaim the road near the left abutment area. Approximately 2,000 CY will be used to construct the road to the Edsall cabin.

Of the 83,800 CY excavated in the auxiliary spillway approximately 15% is expected to be waste due to cobbles and boulders. This material will be used as riprap or placed on the east side of the dam near the principal spillway to construct a parking area. A shrinkage factor of 10% is expected as the excavated material is placed in compacted

fill. This yields 63,000 CY of material. Approximately 56,600 CY will be used for embankment and road base material as described above. The remaining 6,250 CY will be consumed in the processing of drain fill and road surface coarse material. The excavation and fill requirements are approximately balanced.

Static Stability

Stability of the earth reinforced structure portion was evaluated. Conditions of static loading were imposed by the additional weight on the embankment from the retaining structure and by the higher reservoir water surfaces against the embankment and retaining structure. Evaluations of embankment stability for steady-state seepage and reservoir drawdown were completed.

Stability computations for the existing embankment and the modified embankment section with the earth reinforced structure under steady-state seepage and rapid reservoir drawdown were made using appropriate static stability methods. The results of embankment static stability computations are shown in Table VI.1.

Table VI.1
Results of Embankment Static Stability Analysis

Condition	Critical Failure Surface	Safety Factors (calc.)	(recom.)
Existing embankment			
Steady-State Seepage	Downstream-Circular	1.7	1.5
Rapid Drawdown	Upstream-Circular	1.3	1.2
Modified Embankment with Earth reinforced structure			
Steady-State Seepage	Downstream-Circular	1.6	1.5
Rapid Drawdown	Upstream-Circular	1.2	1.2

These results show that the additional load from the retaining wall system and higher reservoir water surfaces has only minor effect on the embankment stability. The computed minimum factors of safety are within acceptable limits for these conditions. A dynamic analysis was not performed as the analysis of the existing structure demonstrated this factor was not critical.

Stability of the earthfill portion of the embankment is essentially the same as the minimum safety factors listed above for the existing embankment. Stability for the earthfill portion of the embankment is not a problem.

Seepage Control

The earth reinforced structure system must provide a relatively watertight barrier and assurance that seepage during high reservoir levels would not affect stability. Flood routing studies showed that the reservoir water surface could be above the normal water surface elevation for as long as 3 weeks during a snowmelt flood event. Therefore, the structure must be capable of providing the necessary protection against seepage that could affect the integrity of the structure or embankment.

A viable means of providing a water barrier is to seal all joints on the upstream retaining structure wall. This will be accomplished by applying a waterproof flexible membrane over the joints on the inside face of the wall, as shown on Exhibit A-8. Assurance of a continuous membrane-to-wall seal would be difficult to control during construction. Therefore, as a defense design measure, it is necessary to provide zoning of materials within the earth reinforced structure section to further control any seepage not stopped by the membrane. This is accomplished by using the compacted sand and gravel drain with a seepage collection pipe as shown in Exhibit A-8.

To maintain stability with an increase of 10 feet in the pool elevation, the phreatic surface must be maintained at near the elevation of the existing phreatic surface. This will be accomplished by constructing an impervious barrier trench with a collector drain at the bottom of the trench as shown on Exhibit A-8. The barrier trench will have an impervious fabricated membrane (equivalent to Hypalon) to provide a positive barrier.

Two manholes will be located along the seepage barrier trench to allow monitoring and maintenance.

Principal Spillway

The existing spillway for Middle Creek Dam discharges water into a tributary of Hyalite Creek approximately 85 feet above the Hyalite Creek channel. Passage of spillway discharges has caused significant erosion in the downstream portion of this tributary. The spillway, though large enough to carry the 500-year flow, has experienced severe weathering damage. In its present condition, a large flow could cause severe damage.

The proposed principal spillway rehabilitation will provide for passage of the 500-year flood without damage. The rehabilitation plan for the principal spillway includes construction of a new spillway within the old spillway, an earth channel leading from the discharge area of the existing spillway to a point on the slope above Hyalite Creek, and a baffled apron drop to Hyalite Creek. Exhibits A-1 to A-6 show the general details of the key features established above. The design of each feature will be discussed below.

Inlet Crest. An elevated labyrinth weir with sloping upstream face will be placed on the upstream side of the existing ogee crest. The elevation of the crest has been set at 6,721.0 feet NGVD. This is 10.2 feet above the existing ogee crest. The

overall length of the crest is 143 feet. Discharge over the crest falls 4 feet to the level apron waterway constructed on consolidated fill. The configuration of the labyrinth is based on studies conducted by Hay and Taylor (Hay and Taylor, 1970). At the design head, the crest coefficient is 3.52. Exhibit A-4 details the weir configuration.

Concrete Chute. The level apron transitions through a vertical curve to point of tangency with the existing chute floor with a slope of 67%. The chute continues at a slope of 67% to an intersection with the basin floor. The walls of the new chute are cast against the floor of the existing chute on the inside of the existing walls. The upper walls will be extended to elevations necessary to satisfy freeboard or top of dam constraints. A prestressed concrete bridge will span the 37-foot chute. The bottom elevation of the bridge is set at elevation 6,723.3 feet NGVD, which will limit the flow entering the principal spillway during the PMF to 3,400 cfs. This elevation provides a 6.3-foot opening through the spillway that should not be affected by clogging. Exhibit A-4 shows the proposed chute.

Stilling Basin. The existing stilling basin will be demolished as it is in very poor condition. A new U.S. Bureau of Reclamation (USBR) Type III basin will be installed in its place (USBR, 1977). The basin is suggested for use when the Froude number of the incoming flow is greater than 4.5 and the velocity is less than 60 fps which is the case in this design. The basic features of this basin, shown in Exhibit A-4, include chute blocks, baffle blocks, and an end sill, all of which aid in dissipating energy and shortening the length of basin required. The basin has a length of only 23 feet, while without these features a basin length of over 30 feet would be required. This results in a considerable savings in concrete

and cost. Proper operation of the basin is dependent upon the required tailwater depth which, at the design discharge, is 8.4 feet. This depth is a function of the hydraulic characteristics of the outflow channel and the baffled apron inlet elevation. Exhibit A-4 shows the proposed stilling basin.

Channel. Immediately beyond the stilling basin, the channel will be widened slightly to lower velocities at the design discharge. A dike across the meadow downstream directs the water into a grassed channel which terminates at the intake of the proposed baffled apron drop. Nonerodible velocities of less than 5 fps are maintained in the grassed channel. The minimum bottom width in the channel is 15 feet, and the side slopes are 2.5H:1V. The meadow dike is designed to overtop for flows greater than the 500-year discharge. The channel banks maintain 3.5 feet of freeboard as recommended by the USBR. Exhibit A-1 details the channel earthwork.

Baffled Apron Drop. A 30-foot-wide baffled apron drop is proposed to convey the 500-year flood without damage to Hyalite Creek, approximately 85 feet below. This type of structure was chosen due to the lack of space for conventional stilling basin. The crest of the baffled apron drop is located at an elevation which maintains nonerodible velocities in the channel upstream. The required crest elevation is 6,688.7 feet NGVD, which is greater than the channel invert through the meadow (see Exhibit A-3). Drainage of the channel following flood events will be accomplished by natural seepage or installation of a small culvert through the dike. The baffle apron drop is designed with a 2H:1V chute slope. USBR design standards were generally followed (USBR, 1978). The tailrace of the baffled apron drop is designed to be protected by riprap, which is installed integrally with the low-level outlet protection. The proposed baffled apron drop is shown in Exhibit A-5.

Low-Level Outlet Protection

Serious bank erosion beyond the low-level outlet will be alleviated in the proposed plan. Since the design of the principal spillway will be such that it can be used frequently, the releases through the low-level outlet can be limited to those required for downstream use. The maximum historic monthly outflow was 300 cfs (July 1975). The outflows will be limited to this value. The exit velocity in the conduit flowing full at 300 cfs is 13.4 fps. At this velocity it is doubtful that the flow will uniformly expand in the outlet transition. It is assumed that local velocities near the bottom of the outlet transition can be 13.4 fps. A short section of 27-inch nominal size riprap will stabilize the bottom and banks until the flow has had a chance to expand. The left bank will be cut back to a stable 2H:1V slope. Riprap protection of the banks along both sides of the outlet channel to a point where the flow expands to uniform conditions completes the outlet protection measures. The proposed outlet protection is shown in Exhibit A-1.

Effect of Increased Water Levels on Gate House

The top of the gate house walls is presently at elevation 6,724.0 feet NGVD. The water surface elevation during the occurrence of the 500-year flood will be 6,722.6 feet NGVD or 1.4 feet below the top of wall elevation. This is less than the minimum required freeboard of 2.1 feet so small amounts of water can be expected to splash onto the structure. During the PMF, the water surface will be 5.9 feet above the walls and may cause limited damage. Following large, infrequent, flood events, the gate house can be pumped dry with the existing jet pump at the base of the tower. The risk of the damage from extreme flood events is not great enough to warrant raising the control tower and gate house.

LAND RIGHTS

Enlargement of the dam and reservoir will result in an increase in both normal water surface and maximum flood pool elevations.

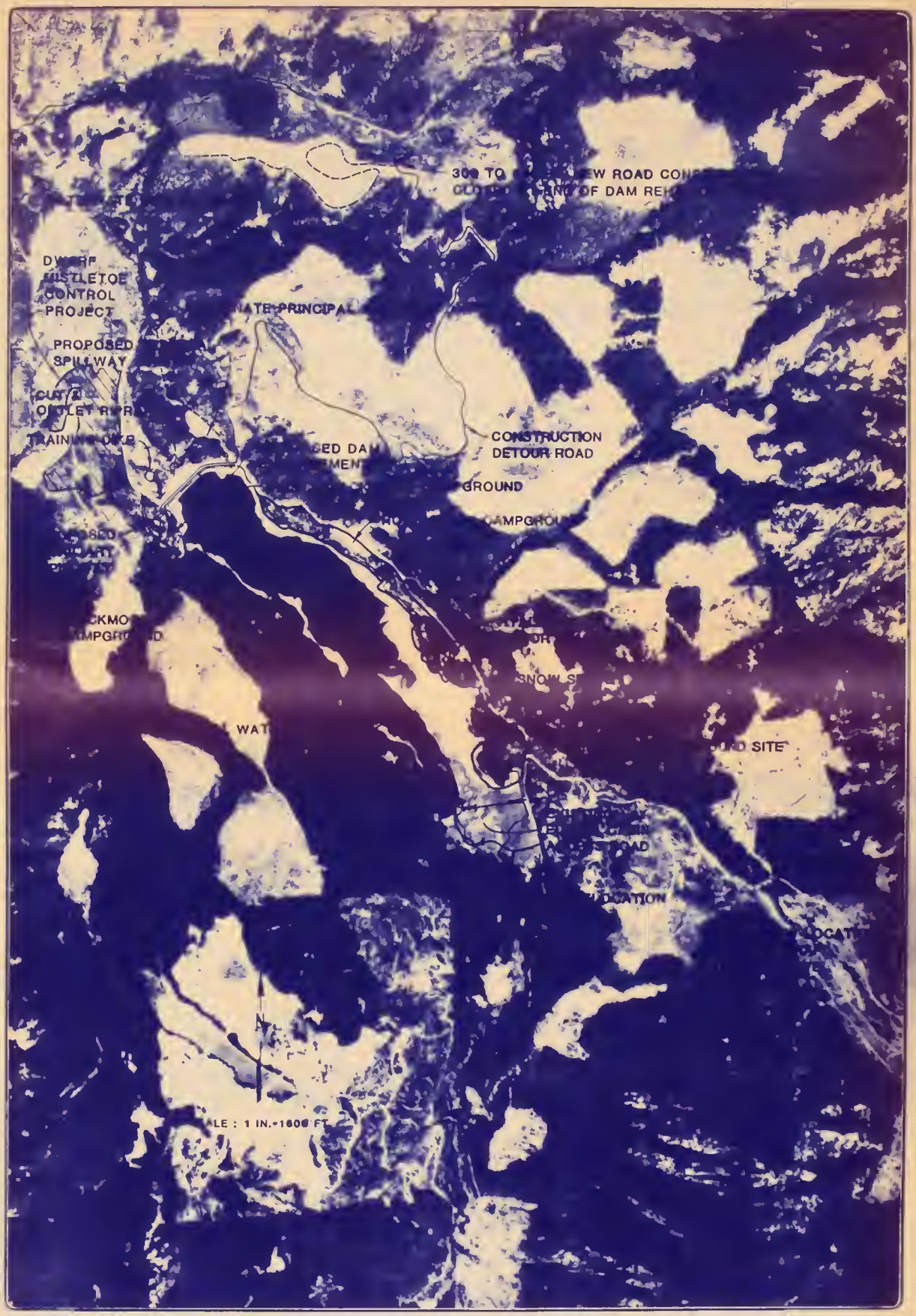
Several parcels of land will be impacted by the proposed project in a number of ways (see Figure VI.1). An auxiliary spillway is planned on the left abutment and impacts the existing Blackmore Campground. The proposed plan is to increase the dam crest and reservoir normal water surface elevation.

Middle Creek Dam and Reservoir are located on three sections of land in Township 4S Range 6E. Project lines in Section 15 and 22 are on national forest lands and operate under a Forest Service special use permit. Section 23 is managed by the Forest Service with the exception of the following land areas:

1. State purchased 66.05 acres from William S. Bole.
2. Hyalite Junior Camp (5.8 acres) belonging to Gallatin County.
3. A 0.73-acre cabin site tract belonging to Wayne Edsall in the NW1/4, SW1/4.

The existing lands listed below are all affected in some degree by the proposal for rehabilitation of the dam and reservoir. The effects are caused by the proposed plan to build an auxiliary spillway in the left abutment area, to increase reservoir storage and surface area, and to raise the dam, increasing the maximum flood pool elevation.

Some existing camping and picnic sites will be removed as a result of the proposed action. Losses will be mitigated. Established undeveloped campsites at Chisholm will be removed, two picnic tables and the boat launch parking area at Hood



MIDDLE CREEK DAM REHABILITATION

VICINITY MAP

8M087.113

SEPTEMBER 1984

FIGURE VI.1

HEM ASSOCIATES
ENGINEERS PLANNERS

Creek Campground will be flooded, and Blackmore Campground will be removed for installation of the auxiliary spillway. Besides the loss of existing facilities, the plans for developing Chisholm site and Lower Blackmore will also be modified (USFS, 1984).

Blackmore Campground

The Blackmore Campground is located in the southwest quarter of Section 15, Township 4S, Range 6E. Campground facilities will be removed to allow for construction of the auxiliary spillway through the left abutment area. To maintain a flood flow capacity, brush and trees will be removed. This area will no longer provide camping opportunities but will be converted to a day use area. The use of this area for an auxiliary spillway would be covered with the new special use permit. The campsites removed will be replaced in the proposed Chisholm Campground.

Hood Creek Campground

Hood Creek Campground is along the northern shore of the lake in Sections 15 and 16. Except for the boat trailer storage area and two picnic tables, the facilities at Hood Creek Campground are high in elevation above the lake and would not be affected by the proposals. A relocation of the boat ramp near the dam to the auxiliary spillway area is proposed. The remaining boat ramp will be raised above the proposed reservoir level.

Hyalite Junior Camp

An 8.2-foot increase in the full pool elevation would not effect structures at the camp but would inundate additional land. The reservoir side of the camp properties are loosely

defined as the high water mark of the reservoir. The portion of the camp in Section 22 may require amendments to the USFS special use permit. The fee land in Section 23 may require negotiation for land rights with the Gallatin County Commissioners.

Soil Conservation Service Snow Course

The Hood Meadow Snow Course No. 10-DO3 is located in the SW1/4, NW1/4, Section 23, Township 4S, Range 6E. An increase in the full pool will at high stage inundate many of the ten stations on the snow course. Normally during the snow measuring season, the reservoir elevation is several feet lower than maximum pool and, therefore, would not interfere with the snow measurements. The Soil Conservation Service (SCS) should decide whether or not it is necessary to move the snow course. If there is a requirement to move the course, SCS officials have indicated that a one or two year warning is sufficient for them to reestablish additional points at higher elevations so the records for the two locations can be correlated. The present course is located on State-owned land. However, the USFS at one time issued a special use permit apparently assuming that the land was USFS land.

Proposed Chisholm Campground

The proposed site for the campground will be developed to replace losses in the Blackmore and Hood Creek Campground areas. The plan to increase the full pool 8.2 feet would be confined within the State property. The proposed location for the campground will match the new proposed reservoir shoreline. Figure VI.1 shows the site proposed by DNRC and DFWP. The proposed plan includes both State and USFS lands. Existing pit toilets on the site will be removed before the reservoir level is raised.

Edsall Cabin

A small portion of the property would be inundated by an 8.2 foot increased full pool. Negotiations with the property owner will be required. Access will be moved upstream. The existing road embankment will be removed.

Dwarf Mistletoe Control Project

The rehabilitation project area will not overlap the control project area. Vegetation damage will not occur. Additional signing and construction contract conditions may be required to insure non-use of the control area.

ACCESS ROADS

Traffic During Construction

During construction of the earth reinforced structure section, traffic will be detoured onto a single lane roadway located on the downstream face of the dam (Exhibit A-8 in Appendix A). This roadway will have a gravel surface, a steel and wood post guardrail on the downslope side and a woven wire fence between the earthen reinforced structure and the roadway. This roadway will then continue on the embankment section and connect to the main road on a berm located in front of the principal spillway. The latter portion of the detour will be a two-way section. This detour will serve as the primary method of routing traffic through the construction area. Access and egress during nonconstruction hours will be allowed.

Traffic will be controlled during the construction season by flag persons stationed on each end or by one flag person controlling a stop light located at each end of the one-way section of the detour road. As a minimum, one-way warning signs will be used. The use of turnouts on the downstream dam face is not feasible due to the steep sideslope. An alternative to the above plan could include an alternative route utilizing existing roads in Lick Creek and Wild Horse Creek. For this option the road would be improved with turnouts added. Traffic and speed would be controlled to maintain the public safety.

An erosion control surface, silt fencing or other appropriate measures will be specified if required to control erosion on the face of the dam and detour road.

Left Abutment Main Road

The main road leading to the left abutment will be rerouted through the auxiliary spillway (Exhibit A-1). This change will allow acceptable grades to the top of the dam; now 10 feet higher. The roadway will have a base course and width suitable for paving. Cross drainage and borrow pits will be provided. This area may require speed reduction signing due to line-of-sight and horizontal curve limitations. A speed reduction would be prudent because of the day use area and traffic stopping to observe the reservoir.

Edsall Cabin Access Road

Presently a causeway and bridge provide access to the Wayne Edsall Cabin, as shown in Figure VI.1. An increase in the permanent pool would inundate this road during certain times of the year. Several alternatives were considered to rectify this

situation. The existing access road could be raised 10 feet throughout its length and the bridge raised 10 feet. This is a very costly alternative due to the amount of earthwork required and the need for riprap protection of the causeway on both sides. Access could be by boat only when the roadway is inundated. The cabin could be purchased and abandoned. The selected solution was to construct a new access road above the high water line but on state land. This route is shown on Figure VI.1. The existing timber bridge would be moved to a new site upstream connecting with this road. The existing road embankment will be removed by wasting fill materials in the road side borrow pits.

DAM SAFETY REQUIREMENTS

This report addresses the findings and recommendations presented in the Phase I report (COE, 1980) and discussed in Chapter 1. As such, this report is classified as a Phase II Study in the National Dam Safety Program (COE, 1975).

At present, dam safety guidelines for the State of Montana have not been finalized; however, the DNRC has suggested that all non-federal dams have a plan of rehabilitation prepared by 1990 and that the work be completed shortly thereafter (DNRC, 1986).

ENVIRONMENTAL CONSIDERATIONS

Environmental considerations for the project are discussed in the Environmental Assessment (HKM, 1986) and described in part within this chapter.

CONSIDERATION OF PROPOSALS FROM OTHER AGENCIES

The USFS is planning to pave the road that presently passes over the crest of the dam. Consideration will be given to coordinating these projects to avoid conflicts.

DESIGN SUMMARY

Table VI.2 has been prepared to provide a comparison of the existing situation and the proposed design. All of the pertinent data regarding elevations, excavation and fill volumes, design discharges, and design features are presented. Elevation-area-storage curves are presented in Figure VI.2.

In summary, it is proposed to excavate a large auxiliary spillway through the left abutment and raise the dam 10 feet with a combination of earth reinforced structure and embankment enlargement. The dam crest elevation is such that protection of the structure can be assured during the PMF. The existing principal spillway will be rehabilitated to provide adequate hydraulic capacity for passing the 500-year flood. This will require a new inlet crest, a new chute with increased wall elevations within the existing chute, replacement of the stilling basin, modification of the outflow channel, and a new baffled apron drop structure. The low level outlet releases will be limited to the maximum anticipated conservation releases to minimize streambed protection measures required in the discharge area.

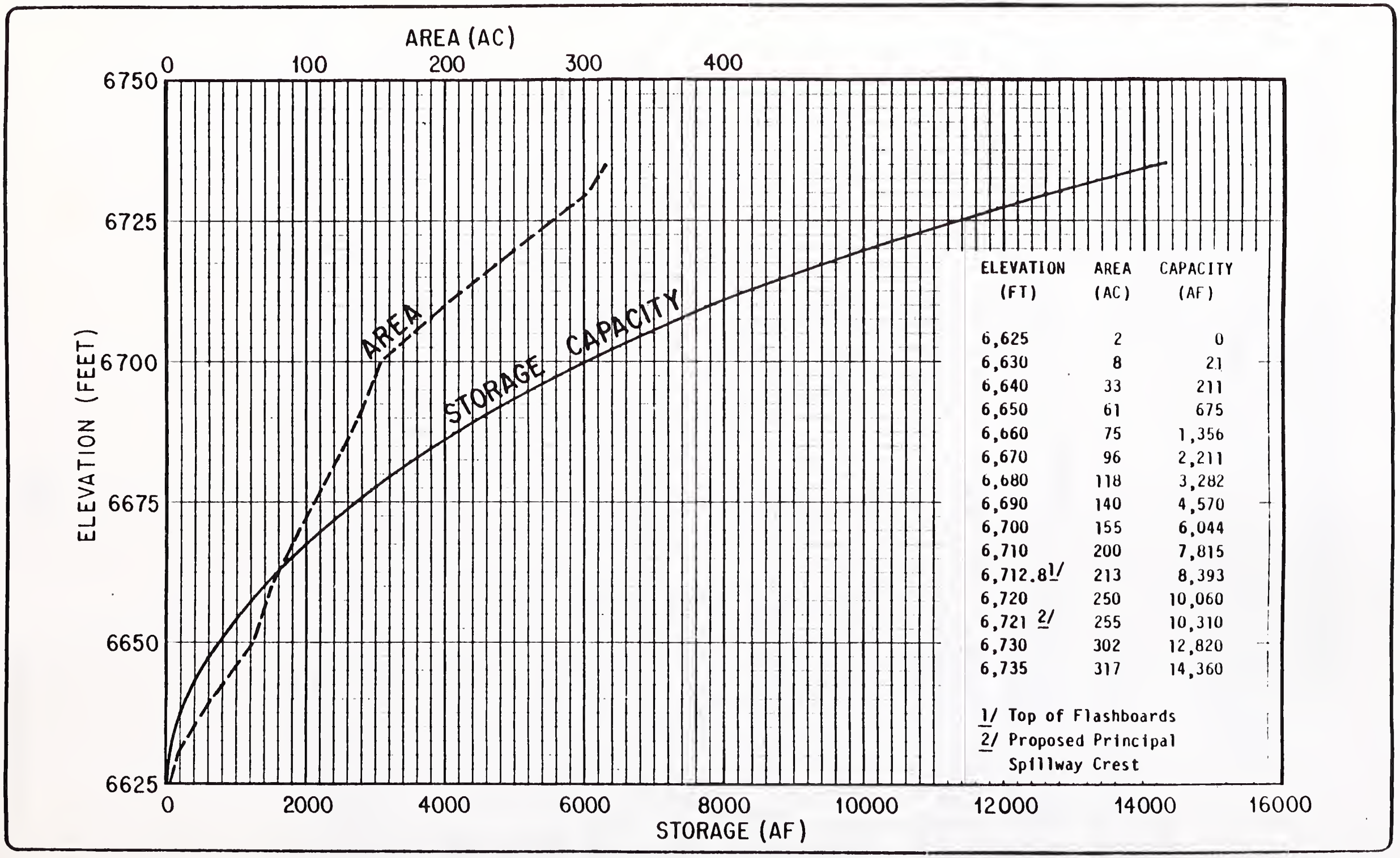
Table VI.2

MIDDLE CREEK DAM AND RESERVOIR

PRINCIPAL CHARACTERISTICS SUMMARY TABLE

Parameter	Existing	Proposed
Structural Height (ft)	117	127
Dam Crest Elevation (ft NGVD)	6,722.0	6,732.0
Normal Water Surface Elev. (ft NGVD)		
(Without Flashboards)	6,710.8	6,721.0
(With Flashboards)	6,712.8	
Active Storage Capacity (AF), 1984		
(Without Flashboards)	7,850	10,184
(With Flashboards)	8,267	
Total Storage Capacity (AF), 1984		
(Without Flashboards)	7,976	10,310
(With Flashboards)	8,393	
500 Yr. Peak Outflow (cfs)		
(Without Flashboards)	1,000	1,000
100 Yr. Peak Outflow (cfs)		
(Without Flashboards)	740	740
Maximum 500 Yr. W.S. Elev. (ft NGVD)	---	6,722.6
Maximum 100 Yr. W.S. Elev. (ft NGVD)	6,713.8	6,721.6
Spillway Design Flood	3/	PMF 2/
Maximum W.S. Elev. (ft NGVD)	3/	6,729.9
Freeboard at Maximum W.S.	3/	1/

1/ Freeboard on earth reinforced structure is 2.1 ft and on conventional fill is 2.3 ft.
2/ The PMF has a peak discharge of 32,400 cfs.
3/ No information is available on hydrologic investigations used in the design of the original structure.



ELEVATION (FT)	AREA (AC)	CAPACITY (AF)
6,625	2	0
6,630	8	21
6,640	33	211
6,650	61	675
6,660	75	1,356
6,670	96	2,211
6,680	118	3,282
6,690	140	4,570
6,700	155	6,044
6,710	200	7,815
6,712.8 1/	213	8,393
6,720	250	10,060
6,721 2/	255	10,310
6,730	302	12,820
6,735	317	14,360

1/ Top of Flashboards
2/ Proposed Principal Spillway Crest

MIDDLE CREEK DAM REHABILITATION

ELEVATION-AREA-CAPACITY CURVES

8M087.113

SEPTEMBER 1984

FIGURE VI.2

HKM ASSOCIATES
ENGINEERS — PLANNERS

CHAPTER VII
ESTIMATED COSTS

ESTIMATES OF COST

Estimates of cost have been prepared for the construction of the proposed project facilities. They are based on the criteria and general design considerations presented in Chapter VI.

The total estimated project cost, based on December 1986 cost levels, plus an allowance for projected price increases, is approximately $5.1 million. This estimate includes, in addition to direct costs, reasonable allowances for contingencies, investigations, engineering, acquisition of lands, DNRC overhead and legal fees, interest during construction, and lending institution participation. A contingency allowance of 25% has been assumed for this project considering the unknown costs of land acquisition, accommodating environmental issues, strict requirements of the USFS concerning access roads and campgrounds and other unknowns associated with obtaining a special use permit to complete this work. Estimated direct costs are shown in Table VII.1. A summary of the estimated project costs, loan obligation, and DNRC contribution appears in Table VII.2.

PROJECTED FUTURE COSTS

It is anticipated that contracts for construction of the project will be awarded by December of 1988. On the basis of past history, the cost of construction can be expected to rise above the present level (December 1986). For this reason, an allowance of 10% has been included to accommodate cost

26-Mar-87

TABLE VII.1

ESTIMATED DIRECT COST OF PROPOSED PROJECT FACILITIES

Proposed Facility	Total Estimated Direct Cost
Principal spillway	$748,200
Auxillary spillway	$342,000
Dam Enlargement	$1,324,900
Access Roads	$242,900
Environmental Mitigation	$103,000
TOTAL DIRECT COST (without contingencies and cost increases)	$2,761,000

TABLE VII.2
SUMMARY OF PROPOSED PROJECT COSTS

Total direct cost		$2,761,000
Contingencies (%)	25%	$690,300
Subtotal		$3,451,300
Project cost increase (%)	10%	$345,100
Subtotal		$3,796,400
Engineering (%)	7.50%	$284,700
Construction administration (%)	6.50%	$246,800
Subtotal		$4,327,900
Reimbursable interest during const.		$98,000
Rights-of-way		$0
Water rights		$10,000
State Construction Administration		$64,000
Lender participation		
Processing of application	$30,000	
Administration of loan	$50,000	
Surveys performed	$0	$80,000
Other costs (Archeology)		$10,000
TOTAL CONSTRUCTION COST		$4,589,900
State Project Administration to-date		$106,000
Loan application report		$500,000
TOTAL PROJECT COST		$5,195,900
Less applicant's contribution		
Rights-of-way	$0	
Water rights	$10,000	
State Contruction Administration	$64,000	
State Project Admin. to-date	$106,000	
Loan application report	$500,000	
Filing fee	$5,000	
State sponsored grant	$496,000	
State financed bond	$107,975	
Other (Archeology)	$10,000	
Subtotal		($1,298,975)
P.L.984 LOAN AND GRANT		$3,896,925
Loan obligation	$3,121,925	
Federal sponsored grant	$775,000	
Less lender expenditures prior to loan (- filing fee)		($25,000)
Less reimbursable interest during construction		($98,000)
TOTAL APPROPRIATION REQUIREMENT		$3,773,925
Less estimated lender administration of loan		($50,000)
TOTAL FUNDS TO BE ADVANCED BY LENDER		$3,723,925

escalation which is expected to occur between the time of preparation of the cost estimate and the award of the construction contract.

LAND ACQUISITION AND RIGHTS-OF-WAY

The dam and most of the reservoir basin is located on USFS and Montana state land. No land acquisition costs are necessary for these areas. There is a private cabin located near the shore on the southwest side of the reservoir. The cabin itself will not be affected by increased water levels but a small portion of the tract on which the cabin stands will be flooded when the reservoir is filled. The PMF will flood additional land but will not reach the cabin floor. This may require a flood easement or outright purchase to be negotiated with the owner of the cabin. Costs to the project have not been determined at this time. It is assumed that these costs will be within the contingency set for this project.

ENGINEERING AND ADMINISTRATION

No contracts for engineering other than work required for the loan application have been entered into by DNRC; therefore, these costs are based on estimates. These estimates include surveying, the preparation of plans and specifications, field inspection, supervision of construction, and assistance in placing the facilities in operation. Costs are included for preparing the initial permit applications such as the USFS special use permit and a 404 COE permit.

Besides the engineering, the DNRC and MCWUA will incur administrative costs consisting of general supervision, environmental mitigation, contract negotiations, water rights, and other miscellaneous items involved in this phase of work. These costs have been included to the extent that they are

directly attributable to construction of the project. DNRC and MCWUA will contribute these costs.

The total estimated cost of 14% for engineering and administration has been applied to the construction cost estimates.

ESTIMATED COST OF PROJECT FACILITIES

A summary of the estimated project costs is presented in Table VII.2. Details of the direct cost estimate are included in Table VII.3.

BUREAU OF RECLAMATION (LENDOR) COST

If the loan is obtained through the Small Reclamation Projects Act, the USBR will incur certain costs during the design and construction of the project, which the DNRC and MCWUA must pay. These costs cover the expenses involved in reviewing and processing the loan application, review of the design, and other costs pertinent to the administration of the loan. The overall costs have been estimated by the Bureau to be $80,000.

STATE ADMINISTRATION AND OTHER COSTS

Administration costs for this project have been incurred by the DNRC. These costs were estimated by DNRC to be $106,000 as of March 1987. Future administrative costs for construction of this project were estimated to be $64,000 (Clark, 1987b). An archeology study of the area has also been completed at a cost to the state of $10,000.

INTEREST DURING CONSTRUCTION

A portion of the water delivered by the project (estimated to be about 42%) is to be used for municipal and industrial purposes. Municipal users will be required to repay interest incurred during construction, compounded annually at the rate of 7-1/2%, for that estimated share of federal funds transferred to the M&I account. These costs amount to approximately $91,000 in principal over the life of the loan. Approximately 5% of the water delivered is estimated to serve lands in excess of 320 acres per owner. These users will also be required to repay interest during construction for this portion of the project. This cost is approximately $6,700. The calculation of reimbursable interest during construction is presented in Table VII.4.

CONSTRUCTION PROGRAM

Preconstruction

The exact program for construction for a project of this scope depends to a great extent upon the date the money becomes available. It has been assumed that the loan application will be approved, and the contract validation successfully completed by July 1, 1987. This is the date, it has been assumed, that the money will become available.

The design is to be finished, complete with approved plans and specifications, by April 1988.

Construction Period

The construction of project facilities is estimated to require 2 years. This allows sufficient time considering the 4- to 5-month construction season at this location. The proposed facilities are to be ready to receive water by May 1991.

TABLE VII.3
Estimate of Direct Costs

Item	Quantity	Unit	Unit Cost	Total
PRINCIPAL SPILLWAY				
Concrete Demolition	265	CY	$165.00	$43,725.00
Upper Spillway Concrete	515	CY	$475.00	$244,625.00
Baffled Apron Concrete	500	CY	$475.00	$237,500.00
Slab Anchors	500	LF	$50.00	$25,000.00
Excavation, Unclassified	15000	CY	$1.75	$26,250.00
Compacted Backfill, Structural	3000	CY	$10.00	$30,000.00
Embankment (Channel & Dike)	10500	CY	$2.50	$26,250.00
Gravel Drain (Filters, Bedding)	350	CY	$14.00	$4.900.00
Riprap (12")	510	CY	$10.00	$5,100.00
Riprap (27")	160	CY	$18.00	$2,880.00
Reinforcing Steel	94000	LB	$0.60	$56,400.00
Underdrains	600	LF	$10.00	$6,000.00
Bridge Superstructure	1050	SF	$31.00	$32,550.00
Clearing & Grubbing	2	Acres	$2,000.00	$4,000.00
Dewatering		LS		$3,000.00
		PRINCIPAL SPILLWAY TOTAL		$748,180.00
AUXILIARY SPILLWAY				
Excavation, Unclassified	85000	CY	$1.75	$148,750.00
Excavation (Gravel, Borrow, Left Abutment)	15000	CY	$1.75	$26,250.00
Embankment (Fill for Gravel Borrow)	15000	CY	$1.50	$22,500.00
Embankment (Dike)	4600	CY	$2.50	$11,500.00
Concrete (Crest)	300	CY	$200.00	$60,000.00
Riprap (27")	800	CY	$18.00	$14,400.00
Riprap (22")	1030	CY	$18.00	$18,540.00
Riprap Filter Bed	220	CY	$14.00	$3,080.00
Road Reclamation	2000	CY	$1.00	$2,000.00
Clearing & Grubbing	15	Acres	$2,000.00	$30,000.00
Topsoil Salvage & Placement	2000	CY	$2.50	$5,000.00
		AUXILIARY SPILLWAY TOTAL		$342,020.00

TABLE VII. 3
Estimate of Direct Costs

Item	Quantity	Unit	Unit Cost	Total
ACCESS ROADS				
Construction Detour				
Earthwork	1200	CY	$6.00	$7,200.00
Gravel Surfacing	520	CY	$10.00	$5,200.00
Temp. Guard Rail	1000	LF	$7.50	$7,500.00
Chainlink Fence	1000	LF	$10.00	$10,000.00
Traffic Control, Operator	400	Hrs	$17.50	$7,000.00
Traffic Control, Devices		LS		$21,000.00
Salvage & Reclamation		LS		$11,100.00
			SUBTOTAL	$69,000.00
Spillway And Dam Crest Road				
Base Gravel	6330	CY	$10.00	$63,300.00
Crushed Aggregate	1380	CY	$14.00	$19,320.00
Asphaltic Concrete	1140	Ton	$25.00	$28,500.00
Asphalt Cement	74	Ton	$180.00	$13,320.00
Geotextile	7470	SY	$3.00	$22,410.00
Cross Drainage	50	LF	$30.00	$1,500.00
			SUBTOTAL	$148,350.00
Edsall Cabin Access				
Excavation, Unclassified	515	CY	$1.75	$901.25
Embankment	2500	CY	$2.50	$6,250.00
Riprap (27")	200	CY	$18.00	$3,600.00
Filter Gravel	50	CY	$14.00	$700.00
Road Surface Gravel	650	CY	$10.00	$6,500.00
Move Timber Bridge		LS		$5,000.00
Cross Drainage	20	LF	$30.00	$600.00
Clearing & Grubbing	1	Acre	$2,000.00	$2,000.00
			SUBTOTAL	$25,551.25
			ACCESS ROADS TOTAL	$242,901.25

TABLE VII. 3
Estimate of Direct Costs

Item	Quantity	Unit	Unit Cost	Total
DAM ENLARGEMENT				
Outlet Tower Catwalk Removal		LS		$1,000.00
Clearing & Grubbing	40	Acres	$2,000.00	$80,000.00
Stripping	9600	CY	$1.75	$16,800.00
Excavation, Unclassified	5500	CY	$1.75	$9,625.00
Trench Excavation	1500	CY	$5.00	$7,500.00
Gravel Drain Fill	2000	CY	$14.00	$28,000.00
Earth Reinforced Struct. Panels	30380	SF	$25.00	$759,500.00
Earth Reinforced Structure Gravel Backfill	12800	CY	$12.00	$153,600.00
Splash Cap	980	Ft	$10.00	$9,800.00
Embankment Fill, Core Material	4250	CY	$4.00	$17,000.00
Embankment Fill, Gravel Shell	25250	CY	$1.50	$37,875.00
Rock Riprap (27")	1450	CY	$18.00	$26,100.00
Impervious Membrane	15840	SF	$0.56	$8,870.40
12" Diameter Drain Pipe	1580	Ft	$14.00	$22,120.00
8" Diameter Drain Pipe	1500	Ft	$10.00	$15,000.00
Guard Rail	1960	Ft	$15.00	$29,400.00
Concrete, Sidewalk	73	CY	$150.00	$10,950.00
Concrete, Foundations	152	CY	$350.00	$53,200.00
Concrete, Manhole, 5' Sections	11	Section	$500.00	$5,500.00
Reinforcing Steel	21800	Lbs	$0.60	$13,080.00
Outlet Tower Catwalk Replacement		LS		$10,000.00
Monitoring Instrumentation		LS		$10,000.00
			DAM ENLARGEMENT TOTAL	$1,324,920.40
ENVIRONMENTAL MITIGATION				
Restore Blackmore Campground Sites To Chisolm Campground	11	Sites	$5,000.00	$55,000.00
Blackmore Day Use Area & Boat Ramp		LS		$20,000.00
Hood Cr Boat Ramp Rework		LS		$5,000.00
Restore Hood Cr Day Use Sites In Chisolm Area	2	Sites	$3,000.00	$6,000.00
Replace Well In Blackmore Area		LS		$2,000.00
Reclamation & Shrub Planting	10	Acres	$1,500.00	$15,000.00
			ENVIRONMENTAL MITIGATION TOTAL	$103,000.00
			TOTAL DIRECT COST	$2,761,021.65

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TABLE VII.4
FEDERAL INTEREST DURING CONSTRUCTION

Year	Appropriation	One-half of Appropriation	Summation of Prior Years Appropriation	Summation of Prior Years Interest	Amount for Computing Interest	Interest 7.5
(1)	(2)	(3)	(4)	(5)	(6)	(7)
FY1	$40,685.75	$20,342.87	$0.00	$0.00	$20,342.87	$1,525.72
FY2	$1,273,241.40	$636,620.70	$40,685.75	$1,525.72	$678,832.16	$50,912.41
FY3	$1,684,997.85	$842,498.93	$1,313,927.15	$52,438.13	$2,208,864.20	$165,664.82
FY4	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
FY5	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Totals	$2,998,925.00					$218,102.94
				Portion of IDC Repaid by M&I 1/		$90,991.16
				Portion of IDC Repaid by Excess Lands 2/		$6,737.37
				TOTAL		$97,728.53
				Round to		$98,000

1/ Total Interest x Total M&I water used (Payout Schedule) / Total water delivered (Payout Schedule).
2/ Excess Portion of ag (465ac/8773ac) times ag portion of IDC (Total IDC minus M&I IDC).

Expenditure of Funds

An estimate of the schedule for the expenditure of funds received from the United States is shown in Table VII.5.

ANNUAL OM&R (OPERATION, MAINTENANCE, AND REPLACEMENT) COSTS

Annual OM&R costs have been assessed at $0.90/AF for a number of years (DNRC, 1986). It is projected that OM&R costs will be $1.00/AF by 1991 when the first payment is due.

TABLE VII.5

SCHEDULE FOR EXPENDITURE OF FUNDS

Fiscal Year	Yearly %	Function	Federal Grant Funds	Federal Loan Funds	Applicant's Contributed Funds
FY1	100%	Water rights			$10,000
	100%	Engineering	$7,126	$27,574	$250,000
	0%	Construct. admin.	$0	$0	$0
	33%	Admin. of loan	$3,388	$13,112	$21,120
	0%	Construction contracts	$0	$0	$0
FY2	0%	Water rights			$0
	0%	Engineering	$0	$0	$0
	50%	Construct. admin.	$0	$0	$123,400
	33%	Admin. of loan	$3,388	$13,112	$21,120
	45%	Construction contracts	$325,650	$1,260,130	$122,600
FY3	0%	Water rights			$0
	0%	Engineering	$0	$0	$0
	50%	Construct. admin.	$25,341	$98,059	$0
	34%	Admin. of loan	$3,491	$13,509	$21,760
	55%	Construction contracts	$406,615	$1,573,430	$107,975
FY4	0%	Water rights			$0
	0%	Engineering	$0	$0	$0
	0%	Construct. admin.	$0	$0	$0
	0%	Admin. of loan	$0	$0	
	0%	Construction contracts	$0	$0	$0
FY5	0%	Water rights			$0
	0%	Engineering	$0	$0	$0
	0%	Construct. admin.	$0	$0	$0
	0%	Admin. of loan	$0	$0	
	0%	Construction contracts	$0	$0	$0
TOTAL APPROPRIATION REQUIREMENT			$775,000	$2,998,925	
APPLICANT'S CONTRIBUTION (after loan approval)					$677,975

CHAPTER VIII
PROJECT EVALUATION

INTRODUCTION

A primary purpose of this chapter is to present an estimate of the Middle Creek Water Users Association's and the City of Bozeman's "ability or willingness to pay", which develops a foundation for the financial program. Loan repayment will be derived by annual assessments paid by two types of users; agricultural, and municipal and industrial (M&I). A secondary purpose of this chapter is to present an estimate of the public benefits of this "multi-purpose" project. Public benefits are presented for agriculture and recreational values. Another public benefit of this project is a safe dam. Those that benefit directly from use of the water will share in the loan repayment as according to their "willingness to pay". State or federal grants may be provided for the balance of costs as described in the Cost Estimate chapter.

AGRICULTURAL PAYMENT CAPACITY

Assumptions and Procedures

Repayment of loan funds allocated to irrigation for the project under the Small Reclamation Projects Act is dependent on the ability of the irrigators to repay their obligation each year. To determine the irrigator's "ability to pay", a representative farm was determined for the land area irrigated by water provided from Hyalite Reservoir. The representative farm was determined by informal surveys with members of the Middle Creek Water Users Association, and consultation with Cooperative Extension Service, Soil Conservation Service, Agricultural Stabilization and Conservation Service and local government personnel.

The representative farm is comprised of 400 acres. The crop mix includes 150 acres of alfalfa-grass hay and 90 acres of barley which are irrigated. Also included are 60 acres of winter wheat (Gaines), 60 acres of subirrigated pasture, 30 acres of summer fallow and 10 acres for the home site and other waste land, none of which are irrigated. The farm includes a livestock herd of 50 cows. The basic enterprise cost data were obtained from the Cooperative Extension Service (Griffith, et.al., 1978 and Cornelius, 1977). Modifications to these data were made to better represent the size and type of operation in the Middle Creek drainage.

The basic data on commodity yields and prices was supplied by the Montana Crop and Livestock Reporting Service (Montana Crop and Livestock Reporting Service, 1983) and the Bureau of Reclamation. All yields are three-year simple average yields for Gallatin County. All prices are twenty-year normalized prices as furnished by the Bureau of Reclamation.

The methodology follows procedures adopted by the Bureau of Reclamation and culminates in a financial summary of the representative farm. For additional details in the calculation of agricultural payment capacity for the Middle Creek Water Users Association members, refer to Appendix B, Farm Budget Analysis worksheets. The most important changes from the Cooperative Extension Service's Enterprise Cost Studies are the separation of interest on investment into debt and equity portions, and the use of sinking fund depreciation. Given the assumptions used in this study, no payment capacity exists but "willingness to pay" can be made available from the return to equity or return to operator's labor.

Most farm budgets are very sensitive to land prices and returns to operator and family labor, management and equity. In this study, land is valued at $525 per acre, a three-year average price for dry cropland in Crop Reporting District #7 (which includes Gallatin, Madison, Beaverhead, Silver Bow and Jefferson counties). The land price information was from unpublished data collected from the Economic Research Service of the USDA.

The returns to operator and family labor are developed in Appendix B. The operator labor was estimated to be 1682 hours at a wage rate of $5.00/hour. The family labor was estimated to be 285 hours at a rate of $3.64/hour. Returns to operator management were estimated at 10% of net farm income.

Returns to equity were based on 12-year average statistics (USDA, 1982). The average rate of return was 3.6% over this period; a return which farmers have come to accept.

Conclusions

As developed in Table VIII.1, no "Payment Capacity" exists for irrigated agriculture in the Middle Creek service area. However, a "Willingness to Pay" can be made available by reducing returns to equity. For purposes of this study, a $5/AF assessment is recommended as a fair and equitable sharing of rehabilitation costs by agriculture. A willingness to pay this

TABLE VIII.1
PAYMENT CAPACITY 1/
MIDDLE CREEK WATER USERS ASSOCIATION, GALLATIN COUNTY, MONTANA
400 ACRE FARM, 390 ACRES FARMED

Crop	Acres or Head (A.or Hd.)	Cropping Pattern (%)	Yield or Weight	Units	Unit Price ($)	Total Product (Units)	Farm Use (Units)	Quantity Sold (Units)	Value ($)
CROPS:									
Alfalfa-Grass Hay	150	39%	3.33	Ton	$67.50	499.5	124	375.5	$25,346
Gaines Winter Wheat	60	15%	66.33	Bu.	4.42	3979.8		3979.8	$17,591
Barley	90	23%	69.33	Bu.	2.70	6239.7	76	6163.7	$16,642
Pasture, Subirrigated	60	15%	5.00	AUM	11.39	300	300	0	$0
Summer Fallow	30	8%							$0
Aftermath Grazing	300		0.30	AUM	11.39	90	46	44	$501
TOTAL CROP SALES									$60,080
LIVESTOCK:									
Cows (cull)	5		10.00	Cwt.	48.30				$2,415
Replacement Heifers	1		7.50	Cwt.	71.43				$536
Bulls (cull)	0.5		18.00	Cwt.	60.60				$545
Steer calves	23		5.25	Cwt.	87.90				$10,614
Heifer calves	16		5.00	Cwt.	77.50				$6,200
TOTAL LIVESTOCK SALES									$20,310

	Farm Perquisites	$6,023
	Gross farm income	$86,413
	Farm Expenses	($48,501)
	Inerest on Indebtedness	($15,722)
	Livestock 1,512	
	Machinery 11,213	
	Real Estate 2,997	
	Net Farm Income	$22,190
	Allowable Returns to Ownership	($24,523)
	Operator Labor 2/ 8,410	
	Family Labor 3/ 1,037	
	Management 4/ 2,219	
	Return to Equity 5/ 12,857	
	Payment Capacity 5/	$0

1/ For detailed analysis see Appendix B.
2/ $5/hr X 1682 hrs, WS 0.1, Appendix B.
3/ $3.64/hr X 285 hrs, WS 0.1, Appendix B.
4/ 10% of net farm income.
5/ Calculation of payment capacity results in a negative number. This is equivalent to reducing the Return to Equity to $10,524 or $26.31/acre. The resulting rate of return on equity is 2.9%. With a $5/ac-ft water cost, and 135 ac-ft of storage required for 240 acres irrigated, the rate of return to equity would be 2.8%.

NO CAPACITY AVAILABLE

amount has been demonstrated by the MCWUA Board of Directors at their 1984 annual meeting. The $5/AF is simply a negotiated value which will allow the farm families enough income to maintain a reasonable standard of living. The farm budget summary in Table VIII.1 shows a net farm income of $22,190 without any allowances for operator and family labor, management, and equity on investment. If the farm would receive 135 acre-feet of water at $5.00 per acre-foot, the annual payment for water of $675 would reduce the net farm income to $21,515. The medium income for farm families is $17,262. Therefore, it is concluded that the Middle Creek irrigators can pay the $5 per acre-foot for water and still maintain a reasonable standard of living compared to other farm families.

There exists approximately 25,000 acres of land that are served by direct flow rights within the Middle Creek drainage. Within this area, approximately 60% are farms which have contracts for Middle Creek storage water or 14,912 acres. It is estimated that 60% of this area or 8,950 acres are irrigated as per the crop mix described earlier. With 5,005 AF of storage contracted for 8,950 acres of irrigation, the average irrigation use is 0.559 AF of storage per acre. Given a 7,016 AF first year contracted capacity (10,184 AF active capacity less a projected 3,168 AF M&I in 1991) and a charge of $5/AF, $35,082 would be generated. Assuming a $1.00 operation and maintenance and reserve fund charge, $4/AF would be available for repayment. It is assumed that the agricultural service area would reduce to approximately 10,250 acres at the end of 40 years and 5,005 AF would be delivered to agriculture with 5,179 AF delivered to M&I service.

MUNICIPAL AND INDUSTRIAL PAYMENT CAPACITY

Needs and Usage

The City of Bozeman has presently contracted for approximately 2,805 AF of water from Middle Creek Reservoir and has expressed a desire for additional water. The new increment of storage is allocated to M&I use for Bozeman and this use repays the remaining obligations of the project. These costs are compared to alternative costs of providing this increment of water. Two alternatives were examined: 1) developing high yield municipal wells, and 2) purchase and transfer of existing storage rights from agricultural to municipal use. Basic engineering and cost estimates for these two alternates are developed in the following paragraphs.

M&I Use. The first step in assessing reasonable value for M&I water is to determine the projected needs of the City of Bozeman, the largest M&I user. The present service area of Bozeman is estimated to cover 9 square miles and served a 1980 population of 21,650. Population projections were made to the year 2020 which is near the end of the 40-year loan repayment period. An Area Wide Water Plan was prepared in 1973 for the City of Bozeman (TDH, 1973). A population of 36,000 by year 2000 was approved for this plan. A service area of 24.3 square miles was included in the 201 Facility Plan. It is assumed that this area would not expand but become denser by year 2020. Most smaller western cities do not exceed a density of 2000 people per square mile. This assumption would set a maximum population limit of 48,600 within this area. However, the following paragraphs develop a more exact projection of population.

Between 1970 and 1980, the population of Bozeman grew from 18,670 to 21,645, an increase of 15.9% Over this same period, the number of housing units rose from 5,736 to 7,971, an increase of 39.0%. For comparison, the population growth for Gallatin County, the State of Montana, and the United States was 31.9, 13.3, and 11.0%, respectively, between 1970 and 1980.

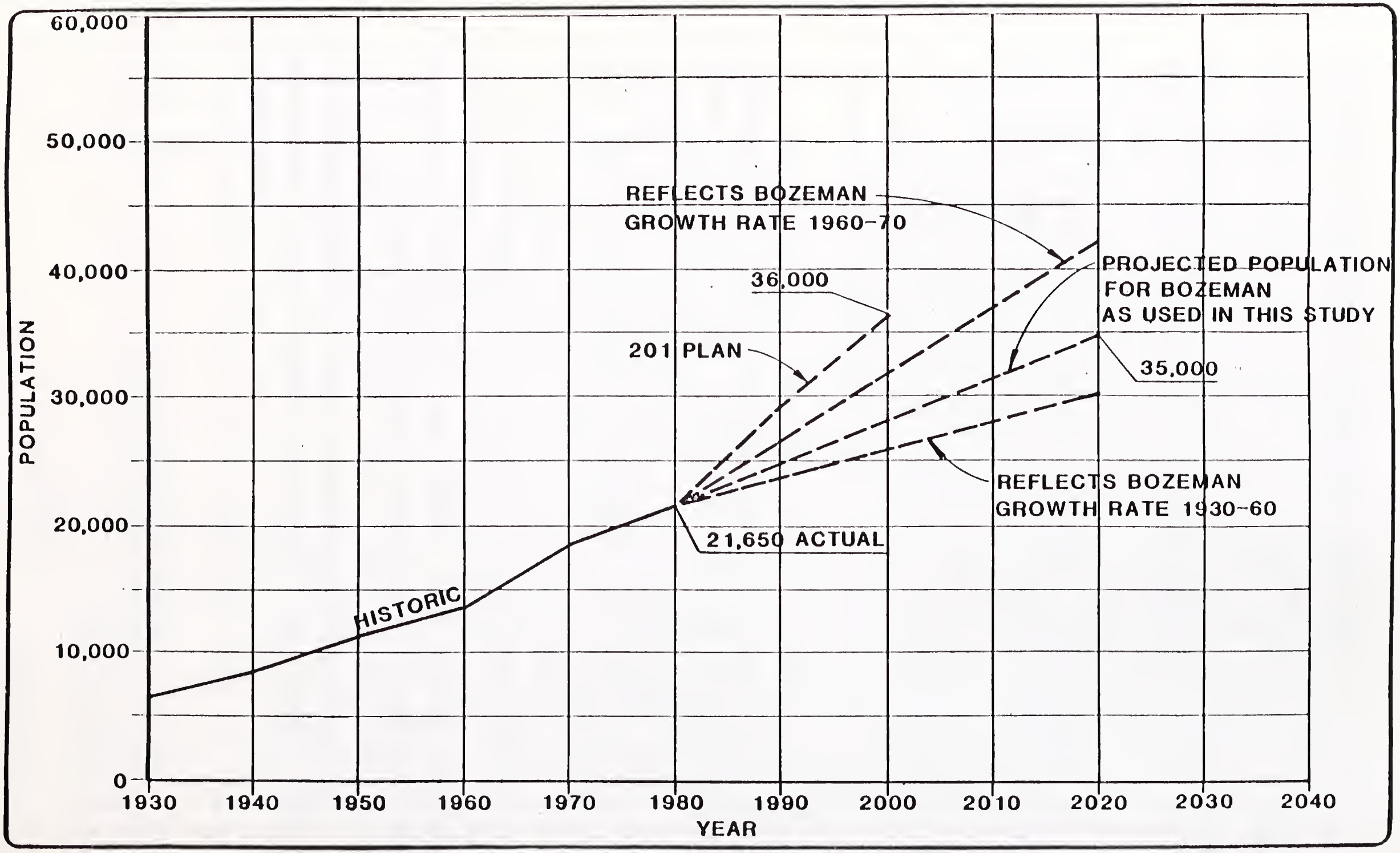
During the past decade, Gallatin County was one of the principal growth areas within Montana. This growth resulted from three primary causes: 1) an expansion of the university enrollment, 2) increases in tourism and travel-related jobs, and 3) growth in durable manufacturing employment. As a result, Gallatin County grew much faster than the state, with much of the growth (over half) resulting from new people moving into the area as opposed to natural population growth (births less deaths).

As was the case in many areas of Montana, the city of Bozeman's population growth was significantly less than the county growth. In other words, most of the growth was found just outside of established city boundaries. City growth, therefore, was often as related to annexation policy as to economic activity.

The future local population growth rate is likely to be slow in comparison to the last decade[1/]. There is, however, every indication that Gallatin County will continue to experience population increases beyond the natural growth level.

Aside from the population trends shown in Figure VIII.1, no "official" projections (state or federal) exist for Bozeman. However, several alternative forecasts were explored in the development of the long-term water demand forecast for the

1/ Many Montana economists/demographers expect that tourism expansion and university enrollment growth rates will decline in the future, thereby reducing Gallatin County's historical population growth rate.



MIDDLE CREEK DAM REHABILITATION

POPULATION TREND BOZEMAN, MONTANA

8M087.113

SEPTEMBER 1984

FIGURE VIII.1

HKM ASSOCIATES
ENGINEERS-PLANNERS

city. For example, a simple extrapolation of the historical population levels found in Figure VIII.1 suggest that if the historical growth trend were to continue the population of Bozeman would increase to approximately 27,500 by the year 2000. This level (27,500) would represent approximately 12,500 households versus the reported 1980 census household level of 7,512 for the city proper - a 66% increase. By the year 2020 (near the end of this study's planning horizon), the simple trend suggests a population and household level of approximately 35,000, and 15,000, respectively. For comparison, the MASS/II projection series, developed for the Montana Department of Commerce/U.S. Environmental Protection Agency, suggest Bozeman population levels of between 23,500 and 32,500 by the year 2000 (ECO Northwest, 1982).

The MASS projections (ECO Northwest, 1982) rely on several important assumptions. First, the population proportion of Bozeman relative to the county total remains constant at the 1980 level. Second, the trend series (32,500) assumes that the 1967-79 increase in basic employment by sector would continue into the future. The second assumption may not be valid. Third, the low series (23,500) assumes only a natural growth increase (i.e., no further immigration into the area). The high and low series probably are the extremes of the likely range of population levels.

The MASS projections (ECO Northwest, 1982) call for an increase in the number of households from 7,512 in 1980 to 14,900 in 2000 for the high series and 10,700 for the low series. The high Bozeman household series represents an increase of 98% while the low series represents an increase of 42% over the next 16 years. For comparison, the more recent Census Bureau projections suggest a national increase in household formation (from 1980 to 2000) of 40% versus the MASS/II range of between

42 and 98%. The national projections and low MASS/II projections are similar due to common assumptions of zero net migration and birth and death rates.

If the national census projections (Bureau of the Census 1979 and 1984) are indicative of growth under zero migration conditions, then Bozeman could expect, at the minimum, an increase of approximately 54% in households by the year 2020. Since the MASS projection ends in the year 2000, the simple trend approach represents the only alternative technique for the 2020 projection. As mentioned earlier, the 2020 trend projection calls for a population level of 35,000 and for approximately 15,000 households, which represent increases of 62 and 100%, respectively, from the 1980 census level. The annualized growth rates (compounding) are 1.2% for population and 1.8% for households over the forty-year period 1980-2020. Both growth rates are somewhat lower than the 1970-80 experience when the annual city population and household growth rates averaged 1.5 and 3.4% per year, respectively.

The lower population growth of 1.2% is reflective of an expected statewide slowdown in basic employment growth relative to the 1970s, when growth was unusually strong. The lower rate, nevertheless, still implies continued immigration. The lower household formation rate of 1.8 also reflects a slowdown in comparison to the 1970s, resulting from fewer individuals in the 20- to 30-year-old age bracket (i.e., the end of the "baby boom" phenomenon). In other words, with fewer young people to develop families, household growth rates will be less. Considering the previous discussion, a population of 35,000 is assumed for Bozeman for year 2020. This number will provide a basis for water demands discussed in the following paragraphs.

The next consideration is the projected average yearly usage as compared to available supply. Diversions typically range from 175 GPCD to 450 GPCD for most Montana cities.

Diversions by the City of Bozeman are 310 GPCD (City of Bozeman, 1983). Consumption rates are also estimated at 236 GPCD in this report. Diversions are significantly higher than consumption for several reasons including the following:

- Diversions have been constant but hourly and daily demands of the city are variable, necessitating overflow from regulating reservoirs.

- Cold weather does not allow manipulation of the diversion gates on Bozeman and Hyalite creeks. The gates are set in late fall so that adequate water can be provided throughout the winter, resulting in overflow.

- Water mains are old and pressures are very high in parts of the city. This results in considerable leakage losses.

- Releases from storage in Hyalite Reservoir must be relatively constant.

Consumptive use is high for the following reasons:

- Bozeman delivers water to Montana State University; students may or may not be included in the population numbers.

- Bozeman supports laundries, motels, restaurants and other tourism-related industries which service Yellowstone National Park and other areas. These activities will increase water requirements on a per capita basis.

- Although a metering program is underway, not all residential services are metered.

It is assumed for purposes of this report that the City of Bozeman would continue to improve its system and diversion requirements will decrease. Given the tremendous cost of these improvements and an existing heavy debt load, diversions are not expected to reach city goals by the end of the 40-year projection period. With this in mind, a diversion requirement reduction of 20% or 245 GPCD has been assumed for this study. As developed in the next paragraph, this level of diversion will utilize the storage available in Hyalite Reservoir. It is assumed that purchase of this water will be more economical than the massive expenditures necessary to reduce diversion rates below 245 GPCD.

Given a population of 35,000, the diversion requirement equals 3,130 MGY or 9,606/AF/yr. The diversion requirement must be increased by 1,035 AF (20% x 5,179 AF storage)1/ for instream water loss from Hyalite Reservoir to the diversion headworks for a total supply requirement of 10,641 AF. It has been estimated by the city that Lyman Creek will supply 1,453 AF of average yearly needs, Bozeman Creek - 4,009 AF/yr and the existing Hyalite Reservoir Storage - 2,805 AF/yr, for a total

1/ The 20% reduction has been used historically in delivering water from Hyalite Reservoir to the city diversion. The 5,179 AF is the storage available to City of Bozeman in year 2027 with the proposed 2,334 AF increase in storage plus 40 AF of existing storage not contracted (See Tables IX.4 and IX.5).

of 8,267 AF/yr (City of Bozeman, 1983). A projected need of 10,641 AF would indicate a deficit of 2,374 AF/yr by year 2020. The city could meet demand for water with the existing supply until year 2020 only if the occurrence of projected growth (35,000 population) and minimum diversions (200 GPCD) became an eventuality. Growth and usage are very difficult factors to control. The city would still experience unacceptable short-term shortages during low flow winter periods and hot, dry summer periods without additional storage. Existing operational constraints, requiring summer time diversions similar to irrigation diversions, are also a factor in utilizing the available water supply.

In summary, it can be concluded that the City of Bozeman must secure additional water to meet its future needs. Nearly all of the deficit can be met by Hyalite Reservoir storage. Additional supplies, if needed, will have to be met by development of ground water, additional purchases of agricultural water and improvements to the distribution system.

Ground Water Alternate

The next step of this analysis is to consider alternative sources of water and their costs. This analysis will determine an upper limit for M&I allocations of repayment.

The purpose of this section is to present background information concerning a ground water system to provide an alternate source to satisfy the projected Bozeman water supply deficit for the year 2020. The projected deficit is 2,500 to 4,000 AF/yr (depending upon improvements to the system) on an annual basis and 6 million gallons per day on a peak daily basis.

One of the most important factors concerning the development of ground water as a water supply source, is the geographic location of the source with respect to the point of use. If a source can be found at or near the point of use, then a significant cost advantage might be achieved by a reduced length of delivery line.

Therefore, an evaluation was made of the capability of ground water within and immediately adjacent to Bozeman to sustain the peak daily and average annual demand of the city. Several sources of information were used for the evaluation and included reports published by the U.S. Geological Survey (Hackett, et.al., 1960) and the Bureau of Reclamation (USBR, 1958). Additional sources included published and unpublished reports related to the occurrence of ground water in Bozeman by personnel associated with the Department of Earth Sciences, Montana State University, Bozeman, Montana (Brown and others, 1983). Additional data was obtained from well logs on file with the Montana Bureau of Mines and Geology (MBMG) in Butte, Montana and interviews of MSU Department of Earth Sciences personnel (Custer, 1983), MBMG personnel (Miller, 1983) and a Bozeman area water well driller (Jones, 1983).

The USGS study indicated that large quantities of ground water supplies are available in parts of the Gallatin Valley (USGS, 1960). The study pointed out that the total ground water discharge varies between 120,000 and 320,000 AF/yr and averaged 240,000 AF/yr for the period 1934-1953. The USGS indicated that average specific yield for the Gallatin Valley as a whole, averaged 0.15. The available ground water and specific yield were found to vary from area to area throughout the valley (Bureau of Reclamation, 1958).

Gallatin River Alluvium, Gateway and Belgrade Areas. Only the alluvial deposits on the floor of the Gallatin Valley were found by the USGS to contain ground water in sufficient quantities to support irrigation by pumping from wells. Transmissivity of the alluvium in the Gateway and Belgrade areas of the Gallatin Valley ranged from 6,680 to 89,570 ft^2/day (Bureau of Reclamation, 1958).

Based on the USGS study, the Bureau of Reclamation estimated that a total of 193 irrigation wells completed in the alluvium in the Gallatin Gateway and Belgrade areas of the Gallatin Valley could produce 92,290 AF of water per year. The Bureau of Reclamation proposed to pump the water in July, August and September of each year from the wells for irrigation purposes (Bureau of Reclamation, 1958).

A complete evaluation of the suitability of ground water in the alluvium for drinking water could not be made as all parameters of the Primary Drinking Water Standards were not included in parameters tested by the USGS for the 1960 report. Water from the alluvium was relatively low in dissolved solids and generally a calcium bicarbonate type. The concentration of dissolved solids ranged from 154 to 398 mg/l (Hackett, et.al., 1960).

Bozeman Fan and East Fork Gallatin River Alluvium, Bozeman and Vicinity. Bozeman is located on the Bozeman alluvial fan and the flood plain of the East Gallatin River. The Bozeman alluvial fan, which is composed of material derived from the Gallatin Range, slopes northward from the mouth of Hyalite Canyon where Middle Creek enters the Gallatin Valley. The fan is bounded on the southwest by Goochs Ridge and on the

southeast by Bozeman Creek. It merges with the floor of the Gallatin Valley on its northwest margin and with the floodplain of the East Gallatin River on its northeast margin. Area of the fan is about 56 square miles (Hackett, et.al., 1960).

The transmissivity of the alluvial fan deposits, determined by the USGS at six locations, ranged from 3,480 to 8,690 ft^2/day and averaged about 6,420 ft^2/day. The USGS indicated in 1960 that no more than 500 gpm should be expected from wells completed in these deposits (Hackett, et.al., 1960).

Calcium and bicarbonate were the major constituents of water from the Bozeman fan in samples obtained by the USGS for the 1960 report. Dissolved solids concentrations ranged from 157 to 343 mg/l and were independent of depth. A complete evaluation of the suitability of water from the Bozeman fan for drinking water purposes could not be made due to the lack of data (Hackett, et.al., 1960).

The USGS was unable to determine the transmissivity of the alluvium of the East Gallatin River. Existing data at the time of the USGS study indicated that the alluvium of the East Gallatin River would not yield large quantities of water to wells (Hackett, et.al., 1960).

Several sources were investigated to determine if additional information has become available since 1960 concerning the occurrence and development potential of ground water in or immediately adjacent to Bozeman. The results of a study published by personnel associated with MSU Department of Earth Sciences indicated the presence of a buried valley on the University campus adjacent to Bozeman (Brown, et.al., 1983).

The feasibility of developing these deposits has not been determined and is dependent on additional studies to determine if large quantities of ground water withdrawal can be supported (Brown, et.al., 1983; Custer, 1983).

Approximately 50 well log reports on file with MBMG were reviewed of wells drilled and completed within Bozeman. Purpose of the review was to determine if any ground water development since the 1960 USGS study has revealed the presence of deposits within the city that could support wells of high sustained yield (1,000-1,500 gpm). Most of the logs reviewed were for wells drilled since 1959. Thickness of clay, silt, sand and gravel deposits within the city in the wells drilled since 1959, ranged from 6 to 190 feet and yields ranged from 15 to 500 gpm.

Conclusions. There is no evidence at the present time that an aquifer exists in or immediately adjacent to Bozeman that could support the projected deficit of 2,500 to 4,000 AF/yr or a peak daily demand of 6 million gallons. Based on available data, it appears the alluvial deposits near Gallatin Gateway, approximately 10 miles southwest of Bozeman, are the most favorable for development of ground water as a source to satisfy the City of Bozeman's projected water deficit in the year 2020.

Alternative Costs For Ground Water Development. A site was selected near Gallatin Gateway for six 1000 gpm capacity wells for the ground water alternative (See Service Area Map, Figure III.1, Chapter III). Available USGS and Bureau of Reclamation information indicate that the alluvium in this area could reasonably be expected to support the six production wells. However, a testing program involving drilling and test pumping would be required before a final decision is made to proceed with ground water development in the Gateway area.

Six wells, each producing 1,000 gpm per well and operating 12 hours per day, would be capable of producing 4.32 MGD on an average daily basis and have a peaking capacity ranging between 6.5 MGD (pumping 18 hours per day) and 8.64 MGD (pumping 24 hours per day). The proposed location of the wells and the close interrelationship between ground water and surface water in the Gallatin Valley, could result in from 20 to 90% of the water produced by the wells being induced infiltration from the Gallatin River. The actual amount supplied directly by induced infiltration would depend on the season and location, demand and duration of pumping from the wells.

It was assumed in this alternative that water produced by the wells would be of relatively high quality and would require only disinfection by chlorination as treatment. It was estimated that about 11 miles of 24-inch-diameter transmission line would be required to move the water from the well field to the Bozeman water treatment plant and terminal reservoir.

The capital costs for the well field and transmission line are summarized in Table VIII.2. The annual costs are shown in Table VIII.3. The costs are estimated in 1985 dollars.

Table VIII.2
Summary of Ground Water Capital Costs

	Item	Unit	Quantity	Unit Cost	Extended Cost
1.	Wells	Each	6	$30,000	$180,000
2.	Pumps, Motors and Electrical	HP	840	300	252,000
3.	Valves/Piping	Each	6	20,000	120,000
4.	Well Houses/ Sitework	Each	6	27,000	162,000
5.	Chlorination Equipment	Each	6	7,000	42,000
6.	Telemetry System	L.S.	1	75,000	75,000
		Subtotal			$831,000
	Contingency (20%)				166,200
		Subtotal			$997,200
	Engineering, Legal, Const. Adm. (15%)				149,580
		Total, Well Field			$1,146,780
		Budget			$1,150,000

Table VIII.2 (cont.)
Transmission Pipeline

1.	24 In. Dia. Pipe	L.F.	56,700	$75	$4,252,500
2.	Highway Crossing	Each	2	25,000	50,000
3.	Misc. Valves and Fittings	L.S.	1	50,000	50,000
		Subtotal			$4,352,500
	Contingency (10%)				435,250
		Subtotal			$4,787,750
	Engineering, Legal, Const. Adm. (12%)				574,250
		Total, Transmission Line			$5,362,000

Table VIII.3
Summary of Ground Water Annual Costs

Well Field

Repayment (7-1/2%, 20 years) $1,150,000 x .0794	$91,310
Energy Costs $\frac{840\ HP}{.90\ EFF}$ x .746 $\frac{KW}{HP}$ x 3500 Hrs. x $.035/KWH	85,000
OM&R Costs $1,150,000 x .03	34,500
TOTAL	$210,810

Cost per AF (2,500 AF) = $84.32
(3,000 AF) = $70.27
(4,000 AF) = $52.70

Transmission Pipeline

Repayment (7-1/2%, 40 years) $5,362,000 x .0981	$526,010
OM&R $5,362,000 x .01	53,620
TOTAL	$579,630

Cost per AF (2,500 AF) = $231.85
(3,000 AF) = $193.21
(4,000 AF) = $144.91

Total Cost per AF = $195 to $315

In summary, it is estimated that a well field will result in costs ranging from $50 to $85/AF for water. Costs for transporting the water from a well field near the West Gallatin River to the Bozeman Treatment Plant would add $145 to $230 to the annual costs. Costs could exceed $250/AF for a workable, large scale development of ground water.

Purchase of Agricultural Rights

The City of Bozeman has the option of purchasing direct flow or storage rights from existing users within the Hyalite Creek drainage area. Use of direct flow rights will be limited to the volume of water historically depleted and to a time of use that is consistent with the location and historical use of this water. Thus, purchase of a right that is used for irrigation will yield approximately 1 AF/acre of land from which the water is severed. This value is based on an average net irrigation requirement determined to be 1 AF/acre from calculations by the SCS TR-21 Blaney-Criddle technique (see Chapter IV, Water). It is estimated that the conveyance and on-farm efficiency ranges from 25% to 40% in this basin. This would indicate a diversion of 4 to 2.5 AF/acre, much of which returns to the stream for diversion by other appropriators. For this reason a use different from irrigation should be limited to the actual depletion associated with the irrigation, not the amount historically diverted.

There is also an assumed loss associated with transmission of storage water from the reservoir to the city's point of diversion. This loss has been historically set at approximately 20%. Thus the yield of each acre-foot of water released from storage is 0.8 AF at the city's diversion point.

Prior sales usually establish a market value for rights which are "severed and sold." Sales have been limited in the Bozeman area historically and information is limited. The City of

Bozeman has recently implemented a policy whereby developers of subdivisions desiring annexation must procure adequate water rights in the name of city before annexation. This will likely create additional sales activity in the future.

Three rights have been sold or transferred recently which would indicate a range of values for water rights. The first right was sold by Litchenburg Land and Cattle Company to the City of Bozeman for $61,000. The right consisted of a direct flow of 7.5 cfs with three early priority dates and 50 AF of storage in Hyalite Reservoir. As a part of the approval process with the Water Rights Bureau, DNRC, an agreement was reached as to 300 AF of consumption on 250 acres of land on which the water was applied. A value for nonbeneficial consumptive use was developed and allowed for diversion in the above agreement. This additional consumptive use is a result of several factors including use by trees, willows and other phreatophytes which consume water as a result of the irrigation practices. Evaporation loss in canals is another factor. Deep percolation of water to the ground water system which does not return in time to benefit users downstream is another factor. This consultant does not believe that these uses will cease as a result of severing irrigation water from a small portion of land within the larger system. For example, established trees and willows will still consume water derived from surrounding irrigated fields, canal losses, etc., as their deep root systems are established. Therefore, nonbeneficial consumptive use was not considered in the yield of an agricultural water right transfer. With the 50 AF of storage included, the total amount allowed for diversion by the city was 350 AF. Considering effective rainfall and long-term, weighted consumptive use of all crops, the depletion by irrigation would be closer to 1 AF/acre with a full supply of water, or 250 AF

(see Chapter IV, Water). Thus the initial cost of the water would be $175/AF if 350 AF were yielded or $244/AF if 250 AF were yielded. Given the latter case and amortizing this cost over 40 years at 7-1/2% the annual cost would be $19/AF.

The second case is a Hyalite Reservoir storage contract sold at public auction by the Small Business Association. In this case 50 AF sold for $18,500 or $370/AF. Considering a diversion of 40 AF, the annual cost would be $37/AF given the terms above. It is interesting to note that the local reaction to this sale was one of surprise as to the high value.

The third case evolved out of the city's requirement for a firmer water supply before any additional annexation could occur. In this case 100 AF of Hyalite Reservoir storage was obtained and the contract was transferred to the city. Telephone conversations with the developer indicated a sales price of $11,000 or $110/AF. With 80 AF diverted this cost would amortize to $11/AF given the terms above. This price was deemed reasonable by the local agricultural interests who were probably a factor in determining this value.

One measure of the agricultural value of water is the amount by which control of a right increases land values. Based on conversations with officials of the Federal Land Bank it is estimated that a typical value for irrigated land with a good water supply would be $1,200/acre. An average value for dryland is estimated to be $525/acre. Thus, irrigation water and facilities to deliver it may increase land values by $675/acre. Assuming that the yield of the agricultural right would be 1 AF/Ac, and one-half of the increased land value attributable to the right the annualized cost would be $27/AF. This number should be considered only as a measure of the potential value of the water to irrigated agriculture.

In summary, purchase of agricultural water rights are a definite option for the City of Bozeman, given a price of $11-$37/AF of divertable water. However, resources are limited and purchase prices will increase as the availability of the resource decreases. Also, costs are not included for administrative and legal costs to obtain the rights, react to protests by senior appropriators, etc., which may be incurred with this process. Therefore, a value of $35/AF of stored water was selected for use in this study.

RECREATIONAL VALUES

User Day Values

There are a variety of methods available to estimate recreational values. After reviewing the literature associated with each method, the Federal Resource Planning Act Guidelines were selected as the most appropriate technique to determine the recreational values of the Hyalite Reservoir.

Over the course of several decades, the U.S. Forest Service (USFS) has developed recreational day values for estimating the benefits of public lands. At the present time, their value estimates represent an approximation of the market value of the recreational attributes associated with a lake, in this case Hyalite Reservoir. The estimates (dollars per 12-hour visitor day) embody only the "market" value of the resource itself. Campground fees which are collected from users are a common proxy of market value, while fishing and hiking fees are not levied; therefore, market values must be estimated. The current day use value for fishing is $11.00 and $5.00 for camping (USFS, 1985).

Recreational Visitor Days

Traffic data shows that there are approximately 23,200 recreational trips per year within the basin. Approximately 13,000 of the trips terminate at the reservoir, generating about 33,000 visitors per year or, assuming a six-hour average stay, 16,500 12-hour visitor days per year. The USFS estimates a 25 percent increase in visitor days within 1 to 2 years. Therefore, a value of 20,600 visitor days per year was selected for this study (Christianson, 1987).

Other methods of estimating recreation usage were investigated such as the USFS Recreational Information Management (RIM) system. Since the traffic data is based on an actual count, while other methods require estimating usage; the traffic data was selected as the most accurate method.

The Montana Department of Fish, Wildlife, and Parks (DFWP) estimates that there were between 11,000 and 12,000 three-hour fishing days in the entire basin last year (Holton, 1983). Of this total, approximately 4,900 fishing days (12-hour days) were thought to be associated with the lake itself. Similarly, an unpublished Master's Thesis by Raymond Zubik, Jr. reports approximately 4,700 (12-hour) fishing days for 1981 and 1982 (Zubik, 1983). This fishing day value was slightly higher (5,700) in a 1975 fishing pressure survey conducted by the DFWP. A value of 5,000 fishing days per year was estimated by averaging the DFWP estimate for 1982-83 (4,900), the DFWP estimate for 1975 (5,700), and Zubik's estimate for 1981-82 (4,700). This figure is also assumed to increase by approximately 25 percent within 1 to 2 years.

The annual recreation benefits of the reservoir is presented in Table VIII.4. Over the long term (100 years), the present value of $140,800 annually discounted at 8-7/8% would be

$1,586,200. This value represents the total discounted benefits associated with the reservoir over the life of the proposed rehabilitation.

AGRICULTURAL VALUES

The present Middle Creek facility provides 5,005 AF of storage and irrigates 8,950 acres of land. Average use per acre would be approximately 0.559 AF.

As developed previously, this land could exhibit "willingness to pay" of $5.00/AF of water. "Willingness to pay," however, does not include producer surplus values, that is, the full value of the water to the user. Table VIII.5 provides various estimates of the "total" value of water that the DNRC has used for planning purposes and benefit/cost ratio calculations over the past decade. The current total value of water is estimated to be $35.

The total value embodies both the market value of the water (i.e., actual water payment) plus the net increase in income (i.e., the residual marginal value product) associated with irrigation water use per AF. In other words, if a rancher paid $5/AF diversion including OM&R, the producer surplus would be $30/AF assuming water were valued at $35/AF.

TABLE VIII.4

ESTIMATE OF ANNUAL RECREATION BENEFITS OF HYALITE RESERVOIR

Activity	Recreation Visitor Days	User Day Value	Total Value
Fishing/Boating	6300	$11.00	$69,300
Camping/Hiking/Picnics	14300	$5.00	$71,500
		ANNUAL RECREATION BENEFIT =	$140,800

CALCULATION OF AGRICULTURAL BENEFITS

Discount rate =	8.875%
Project life =	100
Economic Benefit ($/AF) =	$35
Average Agricultural Use 1/ =	58.28%
Annual Ag Benefit =	$207,736
Present Worth Ag Benefit =	$2,340,207

CALCULATION OF M&I BENEFITS

Discount rate =	8.875%
Project life =	100
Economic Benefit ($/AF) =	$35
Average M&I Use 1/ =	41.72%
Annual M&I Benefit =	$148,705
Present Worth M&I Benefit =	$1,675,204

1/ Average use based on percentage of total from Table IX.3.

TABLE VIII.5
IRRIGATION BENEFIT - VALUE PER ACRE-FOOT

Source	Value Per Acre-Foot
Snyder (DNRC)	$37
Corrigall (DNRC)	$17.25
Steinbeck (DNRC)	$30-$40
Vinnard (DNRC)	$32
Yellowstone Impact Study (DNRC, July 1977)	$34
Long (DNRC)	$37
Luft (AMEC Inc.)	$44
Finnie (ECO Northwest, Ltd.)	$34

The Montana values shown in Table VIII.5 are generally similar to the value of water throughout the western United States. Clearly, areas that raise vegetables have higher water values (at least triple); however, the marginal value of western agricultural water (excluding the lower Columbia Basin) averages approximately $35/AF when indexed to 1983 dollars (Frank and Beattie, 1979).

If the city of Bozeman does not immediately use their full allocation out of the new project (which is probable), then approximately 2,000 AF of storage would be available to irrigate additional land. Agricultural benefits are presented in Table VIII.4.

HKM estimates the study area to be approximately 25,000 acres. According to the Montana Crop and Livestock Reporting Service, approximately 60% of harvested lands in Gallatin County are under irrigation. Applying this factor (60%) to the total Middle Creek area would imply, everything being equal, that up

to 15,000 acres could be supplied supplemental water if water were available. The present value of water is $2.3 million.

COST ALLOCATION

Project costs must be allocated to determine the amount of the federal grant under the Small Reclamation Projects Act as the grant amount is based on the costs allocated to recreation. Recreation is defined herein as boating, fishing, camping, picknicking, and hiking activities. Historically, water has been carried over the reservoir providing recreational benefits. This operation will continue in the future and the additional storage will provide higher reservoir levels. A minimum pool of 1120 AF will be maintained with the exception of emergencies. Emergencies would consist of repair or safety of dam conditions and its appurtenant facilities or extremely dry hydrologic conditions (drier than during the history of the reservoir operation since 1954). It is important to note that total benefits from recreation have been claimed as an unsafe dam would be breached and reservoir related recreation benefits would be non-existent. Incremental analysis of the benefits is not applicable in such a dam safety analysis.

Cost allocations were made by use of the Separable Cost-Remaining Benefits method shown in Table VIII.6. Preconstruction and construction costs are as developed in Chapter VII and summarized in Table VII.2. An estimate of the interest during construction (IDC) for total construction costs is developed in Table VIII.7 because the IDC estimate in Chapter VII only accounts for construction costs financed by the federal loan. The interest rate, 8.875 percent, is the federal plan formulation rate for water projects for FY 1987. This rate is used because there are no reimbursable recreation costs. The OM&R cost includes the cost for operating recreational facilities. These costs are estimated by the USFS

TABLE VIII.6

SEPARABLE COSTS - REMAINING BENIFITS ALLOCATION
Interest Rate 8.875% 100 years

Item	Ag and M&I Water Supply Consumptive Use	Recreation Use	Total
COSTS TO BE ALLOCATED:			
Preconstruction			$646,000
Construction			$4,451,900
IDC 1/			$435,000
OM&R capitalized			$214,000
Annual benefits	$356,440	$140,800	$497,240
Capitalized benefits	$4,015,400	$1,586,200	$5,601,600
Single-purpose alt. 2/	$5,037,944	$3,985,000	$9,022,944
Justifiable expenditure	$4,015,400	$1,586,200	$5,601,600
SEPARABLE COSTS:			
Preconstruction	$0	$20,016	$20,016
Construction	$0	$137,940	$137,940
IDC	$0	$13,478	$13,478
OM&R Capitalized	$0	$99,100	$99,100
Remaining justifiable expenditure	$4,015,400	$1,315,666	$5,331,066
Percent distribution	75.32%	24.68%	
ALLOCATED JOINT COSTS			
Preconstruction	$471,496	$154,488	$625,984
Construction	$3,249,308	$1,064,652	$4,313,960
IDC	$317,493	$104,028	$421,521
OM&R Capitalized	$86,544	$28,356	$114,900
TOTAL ALLOCATED COSTS			
Preconstruction	$471,496	$174,504	$646,000
Construction	$3,249,308	$1,202,592	$4,451,900
IDC	$317,493	$117,506	$434,999
OM&R Capitalized	$86,544	$127,456	$214,000
Annual	$7,682	$11,314	$18,996

SUBALLOCATION 3/	Irrigation 42.54%	M&I 30.45%	Recreation 27.01%	Total
Preconstruction	$274,791	$196,705	$174,504	$646,000
Construction	$1,893,717	$1,355,591	$1,202,592	$4,451,900
IDC	$185,037	$132,456	$117,506	$434,999
OM&R Annual	$4,477	$3,205	$11,314	$18,996

1/ From Table VIII.7.
2/ Consumptive use alternative is cost of this project less separable rec costs; Recreation alternative is least cost dam rehabilitation.
3/ Cons. use suballocation based on water use over 40 yr payout (Table IX.3).

TABLE VIII.7

PROJECT INTEREST DURING CONSTRUCTION

Discount Rate	8.875%*
Total Project Cost	$5,195,900
Less Preconstruction	$646,000
Less IDC Estimate	$98,000
	$4,451,900

Year	Distri-bution	Expenditure	One-half of Expenditure	Summation of Prior Years Expenditure	Summation of Prior Years Interest	Amount for Computing Interest	Interest 8.875
FY1	7.5%	$332,320	$166,160	$0	$0	$166,160	$14,747
FY2	42.0%	$1,869,400	$934,700	$332,320	$14,747	$1,281,767	$113,757
FY3	50.5%	$2,250,180	$1,125,090	$2,201,720	$128,503	$3,455,313	$306,659
FY4	0.0%	$0	$0	$0	$0	$0	$0
FY5	0.0%	$0	$0	$0	$0	$0	$0
Totals		$4,451,900					$435,163
						USE	$435,000

* This table is presented as basis for Cost Allocation at 8-7/8% discount rate-actual repayment is at 7-1/2% as shown in Table VII.4

to be $6,500 annually plus $23,000 every ten years for replacement. Benefits are as derived earlier in this chapter. The separable construction costs for recreation are as shown in Table VII.3 for the campground and day use areas plus contingencies, escalation, and engineering. Separable preconstruction and IDC costs are estimated at the same proportion as separable construction costs are to total construction costs. The separable OM&R costs for recreational facilities are $6,500 plus $2,300 (one tenth of $23,000).

CHAPTER IX
FINANCIAL PROGRAM

SUMMARY OF COST ALLOCATION

Allocation of costs will be made on the basis of water delivered on an annual basis. As shown in the payout schedule, Table IX.3, it is assumed that all 10,184 AF can be contracted by the MCWUA in Year One with the majority of the water going to agriculture. All of the newly contracted water (2,334 AF) will be optioned for ultimate M&I use. That increment of new storage not needed for M&I use will be contracted to agriculture on a year-to-year basis at the agricultural rate. It is assumed that as the City of Bozeman grows, more water will be contracted. For purposes of the payout schedule, this process was assumed to occur uniformly over the 40-year repayment period. Water contracts presently held by agriculture (5,005 AF) were assumed to be reserved for long-term contracts. Approximately 58% of the water will be consumed by agriculture and 42% consumed by M&I over a 40-year period. Because all costs allocated to recreation are being paid during construction by federal grant and state contributions, there is no loan repayment obligation allocated to recreation.

SOURCES OF FUNDING

Several sources of financing were examined and the following financial program is recommended. A primary source of funds for the agricultural allocation will be a loan under the Small Reclamation Projects Act of 1956 (P.L. 84-984) as administered by the Bureau of Reclamation. This source of funding would allow interest free repayment of a loan over a 40-year period

for that allocated portion of storage water delivered to lands in commercial agricultural production up to 320 acres per owner. These terms would allow farmers to repay a portion of the loan within the limits of their "willingness to pay." This "willingness to pay" has been assumed to be $5/AF from discussions with DNRC and local farmers. This value was determined by negotiations with the MCWUA during their 1984 annual meeting.

As developed in the Project Evaluation chapter, the public recreational benefit of Hyalite Reservoir equals a discounted value of $1,586,200 over the 100-year life. Given the importance of recreation to this area, it is suggested that a large portion of this value should be contributed as grant monies by the state and federal agencies toward the total project cost. The funds would originate from at least two sources: 1) a grant under the Small Reclamation Projects Act, and 2) matching contributed funds from state sources. As shown in Table IX.1, a grant of one-half of the recreational allocation can be made under the Small Reclamation Projects Act. The exact allowance amount, by equation, is $775,800 but the grant request is rounded to $775,000.

The source of funding for the remaining costs would be a state loan through the Water Development Program funded from Coal Severance Tax Bond proceeds. This state sponsored loan program is administered through the Montana Department of Natural Resources and Conservation, Water Resources Division. Interest rates are currently 7% with a 20-year term.

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TABLE IX.1

DETERMINATION OF MAXIMUM ALLOWABLE FEDERAL GRANT

50% of recreation construction cost	$601,296
100% of recreation preconstruction cost	$174,504
TOTAL ALLOWABLE	$775,800
AMOUNT REQUESTED	$775,000

Sources of Revenue

Repayment of loan amounts will be derived by assessments by the MCWUA. The MCWUA will in turn make a payment to the DNRC. The DNRC will contract for the loan and bond repayment and will secure the loan in the name of the MCWUA, through individual water purchase contracts. The MCWUA shall levy assessments necessary to operate and maintain the dam and to maintain an adequate reserve account.

Two types of assessments will be made at two different rates. First, users falling into the category of M&I will be required to repay their allocated costs with interest. The agricultural users will be required to make a payment of $5 per AF which is the 'willingness to pay' developed in Chapter VIII. The proposed annual assessments are summarized in Table IX.2.

Interest Charges

Those portions of the loan that are allocated to M&I and agricultural excess lands for storage water actually released from the reservoir will bear interest. This allocation has been projected in the payout schedule but will be calculated each year and an appropriate payment made.

Interest for M&I service is based on the percentage of M&I water delivered, compared to the total amount of water delivered for that year. Interest for excess lands is determined as the percentage of the acres of excess land compared to the total acres of irrigated land receiving storage water. The interest rate will be set at the time of signing of the repayment contract. The FY-1987 interest rate is 7-1/2%.

Table IX.2

ANNUAL ASSESSMENT SCHEDULE ($/AF)

	With Grants	
	M&I	AG
P.L. 84-984 Loan and State Bond Repayment	$30.22	$4.00
O,M&R	1.00	1.00
Existing Debt	0.00	0.00
Emergency Fund	0.00	0.00
	$31.22	$5.00

Repayment Schedule

A proposed repayment schedule is presented in Table IX.3 which is subject to modifications due to interest rate changes and/or agreements made during repayment contract negotiations. It should be noted that the schedule does not account for recreation OM&R costs. The costs for operating the campgrounds are an obligation of the USFS and is funded through their budgetary process which is entirely independent of this project. The joint recreational costs for OM&R are paid by the water users.

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TABLE IX 3
DIMENSIAL PROGRAM AND PAYOUT SCHEDULE

Municipal Water Cost	31 22	Ag Water Cost :	5 00	Annual Water Delivered :	10184	State Financed Bond	
Loan (Less IDC, Adj)	3023925	Interest Rate :	7 500%	Municipal Use (1st year):	3167 6	Last Balance -	8103,935
Capital Recovery Factor :	0 079400	Discount Rate :	9 875%	Annual Water Increase :	55 87	Interest Rate :	7 00%
GPR Factor :	1	Starting Year	1991	Minimum Ag Delivery :	5085	Life :	20
Interest During Constr :	219103	0 :	40	Excess Lands Delivery :	280	Payment :	910.192

		-Sales-				----O & M----		-- Revenues--				------ Expenses------			Reserve	Existing	State	Orc Land	Exc Land	Orc Land	Municipal	Municipal	Net	Balance	----Municipal--		Ag	Total	Total Loan
0	Year	Ag Ag	Exc Lands So Tract	Orban	Total	Ag	Municipal	Total	Ag Ag	Exc Lands So Tract	Orban	Total	Ag	Municipal	Total	Balance	Debt	Bond	Portion	IDC	Interest	Portion	IDC	Municipal	Beginning	Total	Interest	Principal	Principal	Payment
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)
1	1991	9750 4	269	173	2930 6	10184	7016	3188	10184	33792	3300	5521	93367	153975	7016	3168	10184	25000	50	10192	0 037	932	9282	0 313	5309	85533	3023925	80147	70541	9606	19203	28859	113940
2	1992	6780 5	260	177	3040 5	10184	6961	3223	10184	33503	3300	5526	85333	335440	6961	3223	10184	25000	50	10192	0 036	927	8138	0 317	5401	81222	2993226	81741	73824	10137	19018	29155	115035
3	1993	6444 7	260	177	3102 3	10184	6905	3279	10184	33223	3300	5528	80855	336304	6905	3279	10184	25000	50	10192	0 036	922	7993	0 322	5576	84810	2955571	83334	71823	11710	18844	30557	118469
4	1994	6108 8	260	177	3158 2	10184	6849	3335	10184	32944	3300	5528	96599	338789	6849	3335	10184	25000	50	10192	0 036	917	7848	0 327	5671	96598	2936514	94927	72008	12839	18673	31512	117934
5	1995	5532 9	260	177	3214 1	10184	6793	3391	10184	32665	3300	5528	100334	339035	6793	3391	10184	25000	50	10192	0 035	912	7698	0 333	5286	92207	2903202	89521	72503	16018	18023	32041	115470
6	1996	6477 1	260	177	3269 0	10184	6737	3447	10184	32385	3300	5528	102408	342289	6737	3447	10184	25000	50	10192	0 035	907	7548	0 338	5403	93975	2870361	88114	72964	15150	18783	33933	113003
7	1997	6421 2	260	177	3325 0	10184	6681	3503	10184	32102	3300	5528	103832	341784	6681	3503	10184	25000	50	10192	0 035	902	7397	0 344	5958	95883	2838139	86787	73187	13600	18528	35128	110805
8	1998	6365 3	260	177	3381 7	10184	6625	3559	10184	31827	3300	5526	105576	344229	6625	3559	10184	25000	50	10192	0 034	897	7244	0 349	6051	97351	2801052	81308	73410	17898	18462	36551	123853
9	1999	6309 4	260	177	3437 6	10184	6569	3615	10184	31542	3300	5526	107321	345494	6569	3615	10184	25000	50	10192	0 034	892	7089	0 355	6146	99040	2764501	82694	73589	19105	18391	37497	125316
10	2000	6253 6	260	177	3493 4	10184	6514	3670	10184	31260	3300	5526	109065	347155	6514	3670	10184	25000	50	10192	0 034	887	6932	0 360	6243	100729	2726599	84408	73702	20706	18335	39041	126743
11	2001	6197 7	260	177	3549 3	10184	6458	3726	10184	30989	3300	5526	110800	348624	6458	3726	10184	25000	50	10192	0 034	882	6774	0 366	6336	102412	2687218	86098	73745	22336	18445	40781	128246
12	2002	6141 8	260	177	3605 2	10184	6402	3782	10184	30709	3300	5526	112553	350060	6402	3782	10184	25000	50	10192	0 033	877	6613	0 371	6431	104105	2644467	87674	73814	23860	18417	42277	129712
13	2003	6086 0	246		3661 0	10184	6346	3838	10184	30430	3300	5526	114290	351556	6346	3838	10184	25000	50	10192	0 033	872	6451	0 377	6526	105794	2604090	89298	73905	25663	18368	44032	131178
14	2004	6030 1	269	1.	3716 9	10184	6290	3894	10166	30150	3309	5526	116042	353018	6290	3894	10164	25000	50	10192	0 033	867	6286	0 382	6623	107402	2560866	100893	73414	27441	18307	45754	132642
15	2005	5974 2	260	177	3772 0	10184	6234	3950	10184	29871	3300	5526	117780	354483	6234	3950	10184	25000	50	10192	0 032	862	6119	0 388	6718	109170	2514332	102454	73357	29117	18256	47533	134197
16	2006	5916 4	260	177	3828 6	10184	6178	4006	10184	29592	3300	5526	119538	355940	6378	4006	10184	25000	50	10192	0 032	857	5949	0 393	6813	110856	2466739	104047	72768	31279	18208	49487	135672
17	2007	5822 5	260	177	3884 5	10184	6122	4062	10184	29312	3300	5526	121275	357433	6122	4062	10164	25000	50	10192	0 032	852	5777	0 399	6906	112547	2417252	105643	72303	33338	18161	51499	137137
18	2008	5806 6	260	177	3940 4	10184	6067	4117	10184	29033	3300	5526	123010	358870	6067	4117	10184	25000	50	10192	0 032	847	5602	0 404	7001	114236	2363753	107235	71835	35400	18117	53516	138502
19	2009	5750 7	260	177	3996 3	10184	6011	4173	10184	28754	3300	5526	124763	360243	6011	4173	10184	25000	50	10192	0 031	842	5425	0 410	7096	115904	2312337	108629	71261	37367	18074	55443	139867
20	2010	5694 9	260	177	4052 1	10184	5955	4229	10184	28474	3300	5526	126507	361573	5955	4229	10184	25000	50	10192	0 031	837	5245	0 415	7191	117612	2256294	110043	70673	40369	18032	58185	140431
21	2011	5639 0	260	177	4108 0	10184	5899	4285	10183	28195	3309	5526	128252	362873	5899	4285	10183	25000	0	0	0 031	832	5061	0 423	3286	123493	2198159	122207	69365	52842	18003	70845	153069
22	2012	5583 1	260	177	4163 8	10184	5843	4341	10184	27916	3300	5526	129996	364178	5643	4341	10184	25000	0	0	0 030	827	4852	0 426	3381	121384	2137264	123400	66005	55395	17994	73389	154594
23	2013	5527 3	260	172	4219 7	10184	5787	4397	10184	27636	3300	5526	131740	366282	5767	4397	10184	25009	0	0	0 030	822	4659	0 432	7410	132863	2057475	125593	64491	58102	17988	76090	156016
24	2014	5470 4	260	177	4275 6	10184	5731	4453	10184	27357	3300	5526	133485	367666	5731	4453	10184	25009	0	9	0 030	817	4422	0 437	7521	134556	1976585	126957	62672	64285	17967	78252	157344
25	2015	5415 5	260	177	4331 5	10184	5676	4508	10184	27076	3300	5526	135229	368833	5676	4508	10184	25000	0	0	0 030	812	4201	0 443	7666	136247	1896426	128581	60966	65615	17969	83564	157949
26	2016	5359 7	260	177	4387 3	10184	5620	4564	10184	26798	3300	5526	136973	370587	5620	4564	10184	25000	0	0	0 029	507	3837	0 448	7361	137935	1812322	130124	60036	69230	17994	87224	158432
27	2017	5303 0	260	177	4443 2	10184	5564	4629	10184	26519	3300	5526	136712	372062	5564	4620	10164	25000	0	0	0 029	501	3740	0 454	7056	139623	1725590	131787	59714	73053	18000	91058	161818
28	2018	5247 9	260	177	4499 1	10164	5508	4676	10184	26240	3300	5526	140462	373526	5506	4676	10164	25000	0	0	0 029	496	3574	0 458	7953	141312	1634538	133360	56208	77073	18022	95095	163744
29	2019	5192 0	260	173	4555 0	10184	5452	4732	10184	25960	3300	5526	142206	374992	5452	4732	10164	25000	0	0	0 029	491	3276	0 465	8046	143000	1539436	134954	53647	81302	18041	99344	164694
30	2020	5136 2	260	177	4610 8	10184	5396	4786	10184	25681	3300	5526	143950	376457	5396	4786	10184	25000	0	0	0 028	486	3033	0 470	8141	144588	1440060	136547	50777	85770	18068	103838	168273
31	2021	5080 3	260	177	4666 7	10184	5340	4844	10184	25402	3300	5526	145894	377922	5340	4844	10164	25000	0	0	0 028	481	2785	0 476	8237	146316	1336252	138135	47666	90473	18096	109569	167338
32	2022	5024 4	260	177	4722 6	10184	5284	4900	10184	25122	3300	5526	147439	379387	5284	4900	10164	25000	0	0	0 028	476	2532	0 481	8332	148065	1223163	139733	44298	95435	18130	113565	166402
33	2023	4968 0	260	177	4778 4	10184	5229	4955	10164	24843	3300	5526	149163	380852	5229	4955	10184	25000	0	0	0 027	471	2274	0 487	8422	149754	1104108	141308	40859	100666	18189	118833	165660
34	2024	4912 7	260	177	4834 3	10184	5173	5011	10164	24563	3300	5526	150927	382316	5173	5011	10164	25000	0	0	0 027	468	2018	0 492	8522	151442	999291	142928	36732	106198	18314	124912	163102
35	2025	4856 8	260	177	4890 2	10164	5117	5067	10184	24284	3300	5526	152671	383781	5117	5062	10164	25000	0	0	0 027	461	1739	0 498	8637	153130	870878	144583	32498	112084	18467	130551	161597
36	2026	4801 0	260	177	4946 0	10184	5061	5123	10184	24005	3300	5526	154416	385247	5061	5123	10164	25000	0	0	0 026	456	1463	0 503	8712	154819	742038	146107	27942	118165	18325	136490	159963
37	2027	4745 3	260	177	5001 8	10184	5005	5178	10184	23725	3300	5526	156160	386711	5005	5179	10184	25000	0	0	0 026	451	1180	0 509	8807	156503	604130	147760	23041	124719	18186	142904	158322
38	2028	4745 0	260	177	5002 8	10184	5005	5178	10184	23725	3300	5526	156162	388173	5005	5178	10184	25000	0	0	0 026	451	891	0 509	8907	156509	481060	147702	17585	130117	18069	148185	156679
39	2029	4745 0	260	177	5002 8	10184	5005	5179	10184	23725	3300	5526	156162	389643	5005	5179	10184	25000	0	0	0 026	451	610	0 509	8907	156509	312275	147702	11910	135792	18020	153812	154751
40	2030	4745 0	260	177	5002 8	10184	5005	5179	10184	23725	3300	5526	352731	163262	5005	5179	10184	25000	0	0	0 026	451	308	9 595	8907	153070	157324	144271	6000	139.63	19.61	153.5.4	303.98
Totals		227012	10450	7200	192969	491369	237413	109947	407369	1133083	52900	221940	5001295	6483359	237413	169347	497360	25000					21356	192935		299590	4529549		4036569	2350089	2294879	235046	3023925	5077923

Loan Factor 9 49 Discount Total Payments 1411582

Column Descriptions - Payout Schedule

Column 1 - Year of repayment.

Column 2 - Calendar year if funds become available on schedule.

Column 3 - Amount of water available for sale for regular commercial agriculture - supplemental irrigation (does not include excess lands)

Column 4 - Amount of water for irrigation of lands in excess of 320 acres per landowner.

Column 5 - Amount of water projected for small tracts (less than 10 acres).

Column 6 - Amount of water projected for urban use.

Column 7 - Total of Columns 3, 4, 5, and 6.

Columns 8, 9 and 10 - O,M&R assessment at $1.00/AF of water sold.

Columns 11 and 12 - Revenue from irrigation assessment. Based on $5.00/AF times Column 3.

Columns 13 and 14 - Revenue required from M&I sources to repay the portion of the loan allocated to M&I purposes and to pay other M&I costs.

Column 15 - Total revenue equals the sum of Columns 11, 12, 13, and 14.

Columns 16,17 and 18 - Expenses in this case are equal to O,M&R assessments.

Column 19 - An emergency reserve fund of $25,000 presently exists and will be maintained.

Column 20 - Existing debt based on payments due on unpaid contracts starting in 1991 at $1.96/AF.

Column 21 - Annual M&I repayment of state financed bond.

Column 22 - Excess lands portion of loan which bears interest - 465 acres excess lands divided by 8,773 acres total commercial irrigation times the ag portion of the loan (1 minus column 25).

Column 23 - Excess lands portion of Interest During Construction which must be repaid with interest - Column 22 times Total IDC times Capital Recovery Factor.

Column 24 - Interest on excess lands portion of loan - Column 22 times Loan Balance (Column 28) times the loan interest rate (7-1/2%).

Column 25 - M&I portion of loan which bears interest - Column 5 plus Column 6 divided by Column 7.

Column 26 - M&I portion of Interest During Construction which must be repaid with interest - Based on Column 25 times Total IDC times Capital Recovery Factor.

Column 27 - Municipal payment available to be applied to loan principal and interest (Column 13 plus Column 14 minus Column 17 minus Column 21).

Column 28 - Principal balance of loan at beginning of year - Calculated by subtracting previous year principal payment (Column 33) from previous year beginning balance (Column 28).

Column 29 - Amount of Municipal revenue available for loan principal and interest payment (Column 27 minus Column 26).

Column 30 - Interest on municipal portion of loan - Column 25 times Column 28 times interest rate (7-1/2%).

Column 31 - Municipal principal payment - Column 29 minus Column 30.

Column 32 - Agricultural principal payment (Column 11 plus Column 12 minus Columns 16, 20, 23, and 24).

Column 33 - Column 31 plus Column 32.

Column 34 - Column 23 plus Column 24 plus Column 26 plus Column 29 plus Column 32.

REFERENCES

Agricultural Stabilization and Conservation Service. 1979. Aerial Photography. Salt Lake City, Utah.

Agricultural Stabilization and Conservation Service. 1980. Aerial Photography. Salt Lake City, Utah.

Agricultural Stabilization and Conservation Service. 1983. Ownership Records. Gallatin County Office, Bozeman, Montana.

American Public Health Association. 1985. Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, D.C.

American Water Works Association. October 1979. Secondary Drinking Water Regulations. OPFLOW, Vol. 5, No. #10. American Water Works Association, Denver, Colorado.

Blue Ribbons of the Big Sky Country Areawide Planning Organization. August 1979. Final Report and Water Quality Management Plan. Bozeman, Montana: The Organization.

Christianson, Nan. March 26, 1987. Telephone Communication. Gallatin National Forest. Bozeman, Montana.

City of Bozeman. September 1983. Municipal Water Inventory. Bozeman, Montana: The City.

City of Bozeman, Montana. 1987. Telephone conversations with City personnel.

Clark, Robert. March 26, 1987a. Telephone Communication. Middle Creek Dam Project Engineer, Montana Department of Natural Resources and Conservation. Helena, Montana.

Clark, Robert. March 30, 1987b. Telephone Communication. Middle Creek Dam Project Engineer, Montana Department of Natural Resources and Conservation. Helena, Montana.

Cornelius, Jim. August 1977. Enterprise Costs for a 200-Head Cow-Calf Ranch Operation in Northern Madison County. Bulletin 1171. Bozeman, Mont.: Montana Cooperative Extension Service.

Culp, G.L. March 1987. Big Changes Ahead for Drinking Water Industry. Vol. 13-No. 3, Water/Engineering & Management. Scranton Gillette communications, Inc., Des Plaines, Illinois.

Custer, Steve. 1983. Interview. Montana State University, Department of Earth Sciences. Bozeman, Montana.

Department of Natural Resources and Conservation. 1983. Middle Creek Dam Design Drawings. Helena, Montana.

Department of Natural Resources and Conservation. 1986. Conversations with DNRC personnel.

ECO Northwest, Ltd. 1982. Montana Alternative Simulation System (MASS/II).

Frank, Michael D. and Bruce R. Beattie. 1979. The Economic Value of Irrigation Water in the Western United States: An Application of Ridge Regression. Technical Report No. 99. College Station, Texas: Texas A&M University.

Gallatin County Courthouse. 1983. Ownership Records. Bozeman, Montana.

Griffith, Duane; Jerry Schaefer; and LeRoy D. Luft. March, 1978. Enterprise Costs for Irrigated Crops in Gallatin County. Bulletin 1182. Bozeman, Montana: Montana Cooperative Extension Service.

HKM Associates. April 1984a. Flood Hydrology, Middle Creek Dam. Billings, Montana: HKM.

HKM Associates. April 1984b. Geotechnical Investigation, Middle Creek Dam. Billings, Montana: HKM.

HKM Associates. November 1983. Hydrologic Potential for Hyalite Creek Watershed. Billings, Montana: HKM.

HKM Associates. February 1985. Middle (Hyalite) Creek Dam Rehabilitation Feasibility Study. Billings, Montana: HKM.

Hackett, et.al. 1960. Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana. U.S. Geological Survey Water Supply Paper 1482. Washington, D.C.: Government Printing Office.

Hay, Nessim and Geoffrey Taylor. 1970. "Performance and Design of Labyrinth Weirs". ASCE Journal of the Hydraulics Division HY11 (November): 233-253.

Holton, George. 1983. Annual Fishing Pressure Survey. Helena, Montana: Montana Department of Fish, Wildlife and Parks.

Jones. 1983. Interview with Bozeman area well driller. Bozeman, Montana.

Lucero, J.M. February 13, 1987. Personal Communication. Hydrologist, U.S. Bureau of Reclamation, Billings, Montana.

Miller. 1983. Interview. Montana Bureau of Mines and Geology. Butte, Montana.

Montana Bureau of Mines and Geology. March 3, 1987. Water Well Drillers on File. Montana Bureau of Mines and Geology. Butte, Montana.

Montana Crop and Livestock Reporting Service. September 1983. Montana Agricultural Statistics. Helena, Montana: The Service.

Montana Department of Health and Environmental Sciences. 1987. Miscellaneous water quality measurements. Helena, Montana.

Montana Department of Natural Resources and Conservation. March 3, 1987. Water Well Drillers Logs on File. Montana Department of Natural Resources and Conservation. Helena, Montana.

Montana State University. 1986. Phone conversations with MSU personnel.

Montana Water Rights Bureau. 1983. SB76 Claims of Record. Helena, Montana.

National Oceanic and Atmospheric Administration. 1974. Climates of the States. Port Washington, N.Y.: Water Information Center, Inc.

State Engineers Office. January 1953. Water Resources Survey, Gallatin County, Montana. Helena, Montana.: The Engineer.

Thomas, Dean & Hoskins. 1973. Area Wide Water Plan, City of Bozeman. Great Falls, Montana: The Engineers.

Thompson, J.C. August 1986. Updating the Safe Drinking Water Act and The Drinking Water Regulations. Water Engineering & Management. Scranton Gillette Communications, Inc., Des Plaines, Illinois.

U.S. Army Corps of Engineers., May 1975. "Recommended Guidelines for Safety Inspection of Dams". In Office of the Chief Engineer's Report to the U.S. Congress, National Program of Inspection of Dams. Volume I, Appendix D. Washington, D.C.: The Corps.

U.S. Army Corps of Engineers. April 1980. Middle Creek Dam, Phase I Inspection Report, National Dam Safety Program. Seattle District. Seattle, Washington.: The Engineers.

U.S. Army Corps of Engineers. March 1981. HEC-3 Reservoir System Analysis for Conservation. Davis, California.: U.S. Hydrologic Engineering Center.

U.S. Bureau of the Census. May, 1979. Projections of the Number of Households and Families: 1979-1995. Washington, D.C.: Government Printing Office.

U.S. Bureau of the Census. May, 1984. Projections of the Population of the United States, by Age, Sex, and Race: 1983-2080. Washington, D.C.: Government Printing Office.

U.S. Bureau of Reclamation. 1977. Design of Small Dams. Washington, D.C.: Government Printing Office.

U.S. Bureau of Reclamation. January 1978. Hydraulic Design of Stilling Basins and Energy Dissipators. EM No. 25. Washington, D.C.: The Bureau.

U.S. Bureau of Reclamation. August 21, 1986. Planning Instruction No. 86-07(7115), Trace Element Data Acquisition and Analysis - Toxic Constituent Studies. U.S. Bureau of Reclamation, Billings, Montana.

U.S. Department of Agriculture. 1982. Economic Indicators of the Farm Sector, Income and Balance Sheet Statistics. Washington, D.C.: Government Printing Office.

U.S. Environmental Protection Agency. March 1979. Methods for Chemical Analysis of Water and Wastes, EPA-60014-79-020. U.S. Environmental Protection Agency, Cincinnati, Ohio.

U.S. Fish and Wildlife Service. 1975. 1975 National Survey of Hunting, Fishing and Wildlife - Associated Recreation. Washington, D.C.: The Service.

U.S. Forest Service. 1985. 1985 RPA Program Update: Resource Benefit Values.

U.S. Forest Service. 1987. Miscellaneous water quality measurements. Bozeman, Montana.

U.S. Geological Survey. 1964-1983. Water Resources Data for Montana. Helena, Montana.: USGS.

U.S. Soil Conservation Service. 1967, Revised 1970. Irrigation Water Requirements. Technical Release No. 21. Washington, D.C.: The Service.

U.S. Soil Conservation Service. 1986. Telephone conversations with SCS personnel.

Zubik, Raymond John, Jr. 1983. The Fishery of Hyalite Reservoir, Montana, With An Evaluation of Cutthroat Trout Reproduction in its Tributaries. Thesis, Montana State University, Bozeman.

EXHIBIT A

A-1 THROUGH A-10

PROPOSED PLANS

1. LABRYINTH WIER
2. EXISTING PRINCIPAL SPILLWAY REHABILITATION
3. SPILLWAY CHANNEL ENLARGEMENT
4. SPILLWAY CHANNEL DIKE
5. BAFFLED APRON DROP
6. OUTLET CHANNEL RIPRAP
7. AUXILIARY SPILLWAY EXCAVATION
8. EARTH REINFORCED STRUCTURE DAM ENLARGEMENT (10 FT HEIGHT INCREASE)
9. CONCRETE SILL
10. DAY USE AREA IMPROVEMENTS
11. ROAD RECLAMATION
12. AUXILIARY SPILLWAY TRAINING DIKE
13. ROAD RELOCATION
14. IMPERVIOUS BARRIER TRENCH AND SEEPAGE DRAIN
15. NEW EMBANKMENT FILL WITH RIPRAP ON UPSTREAM SLOPE.
16. COLLECTOR DRAIN AT BASE OF DOWNSTREAM FACE OF EARTH REINFORCED STRUCTURE WALL
17. ALTERNATE BORROW AREA FOR EARTH REINFORCED STRUCTURE - REPLACED WITH 3' THICK COMPACTED EARTH LINING FROM AUXILARY SPILLWAY EXCAVATION FOR SEEPAGE CONTROL

No.	Revision	By	Date
1	CAMPGROUND REVISED	DNM	1/1987

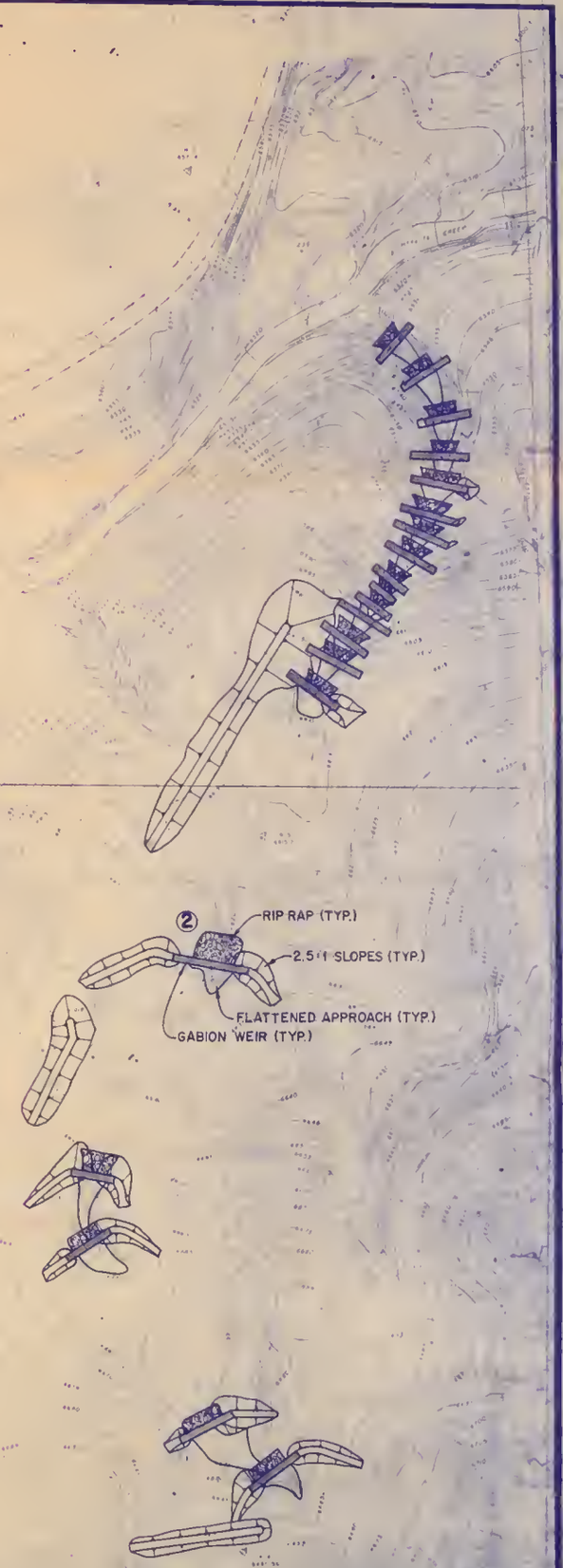
MIDDLE CREEK DAM

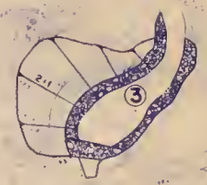
RECOMMENDED GENERAL SITE PLAN

SCS-697-119 SEPTEMBER 1984

EXHIBIT A-1

HKM ASSOCIATES ENGINEERS-PLANNERS


②
RIP RAP (TYP.)
2.5:1 SLOPES (TYP.)
FLATTENED APPROACH (TYP.)
GABION WEIR (TYP.)



HYALITE CREEK RESERVOIR

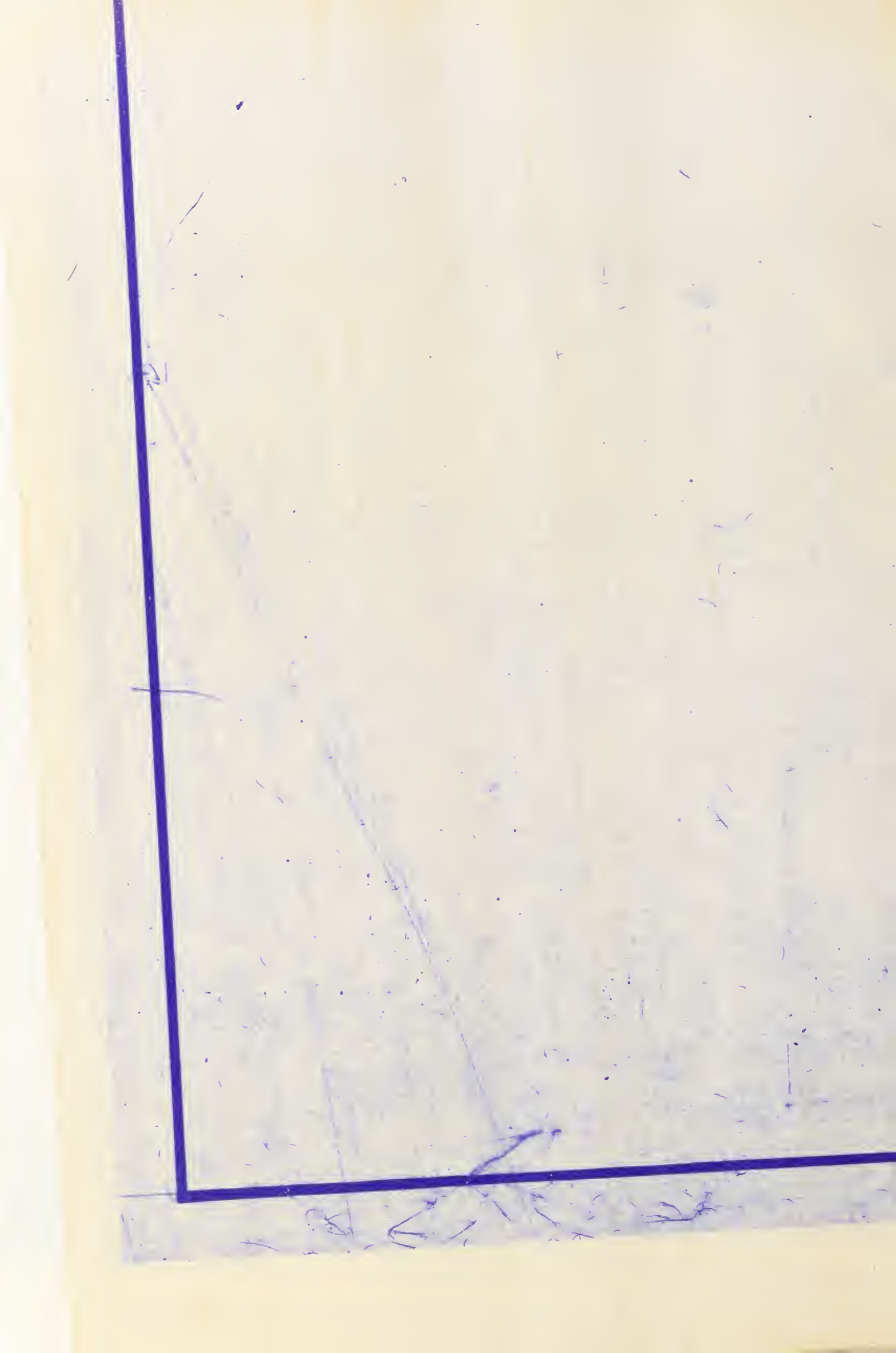
ALTERNATE PLANS

① EXISTING PRINCIPAL SPILLWAY REHABILITATION
② GABION WEIR DROP STRUCTURES
③ OUTLET CHANNEL RIPRAP
④ AUXILIARY SPILLWAY TRAINING DIKE
⑤ ROAD REGRADING
⑥ AUXILIARY SPILLWAY EXCAVATION

NO DAM HEIGHT INCREASE

MIDDLE CREEK DAM
ALTERNATIVE GENERAL SITE PLAN
SM007.113
SEPTEMBER 1994

EXHIBIT A-2
HKM ASSOCIATES
ENGINEERS-PLANNERS



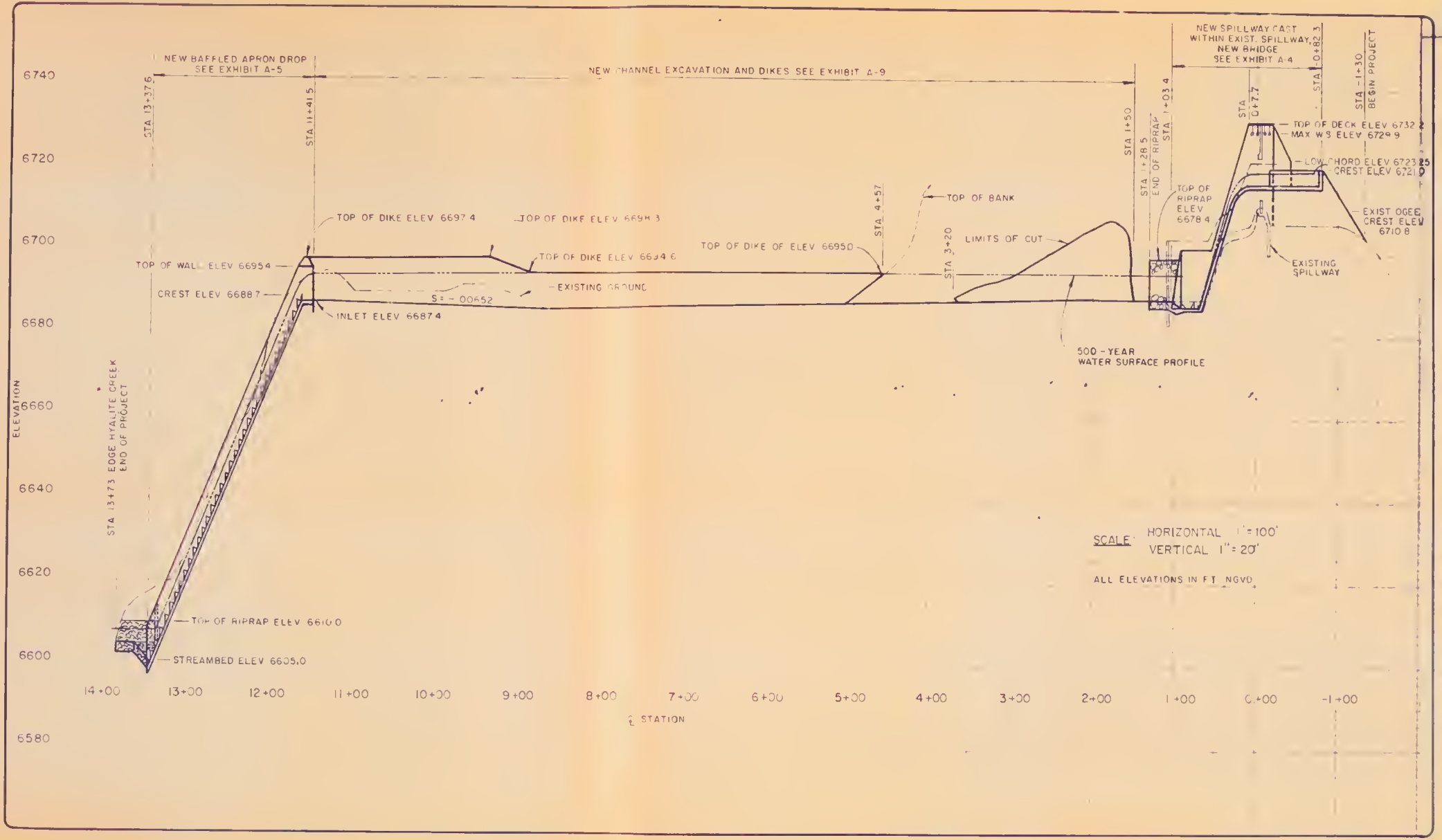


EXHIBIT A-3

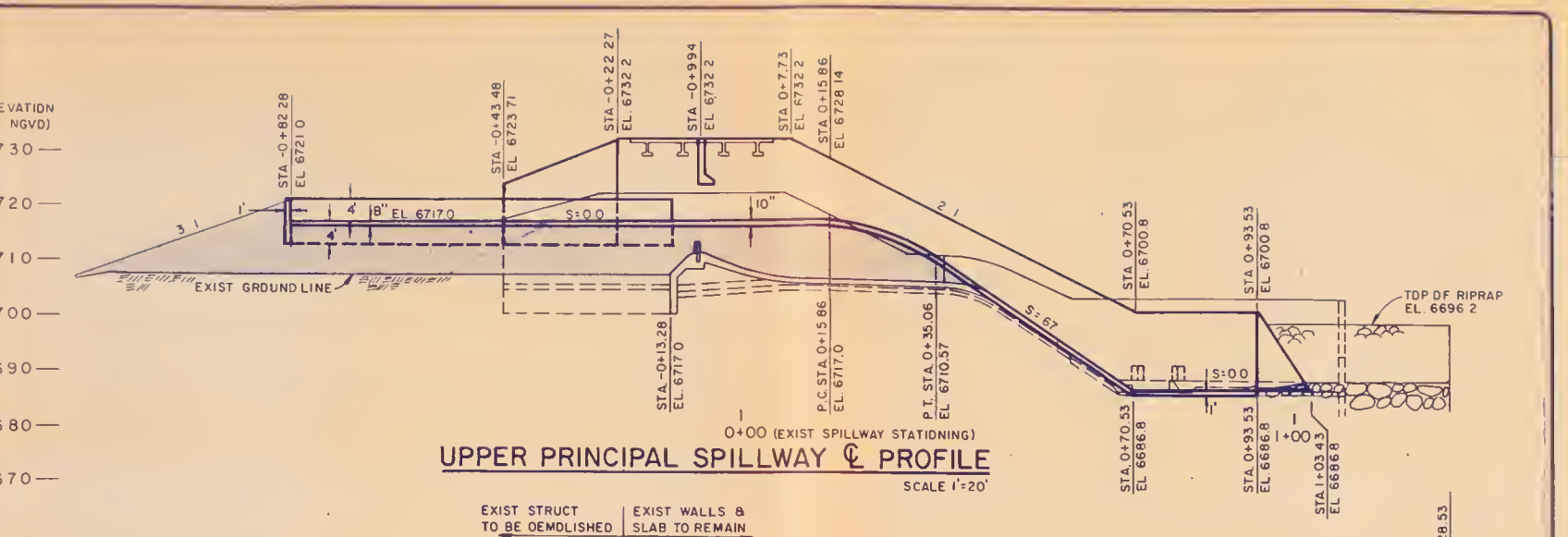
HKM ASSOCIATES
ENGINEERS-PLANNERS

MIDDLE CREEK DAM REHABILITATION

PRINCIPAL SPILLWAY SYSTEM PROFILE

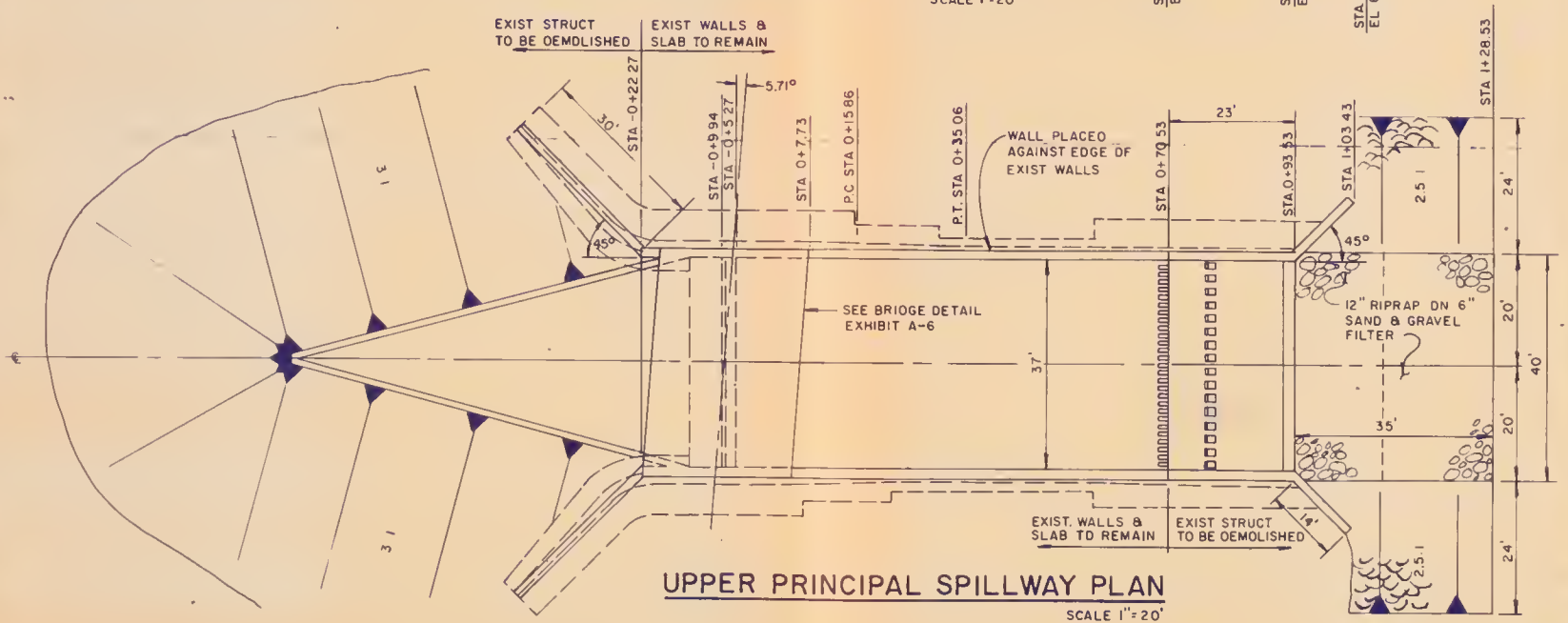
SEPTEMBER 1984

BM667.113



UPPER PRINCIPAL SPILLWAY ℄ PROFILE

SCALE 1"=20'



UPPER PRINCIPAL SPILLWAY PLAN

SCALE 1"=20'

EXHIBIT A-4

HKM ASSOCIATES
ENGINEERS-PLANNERS

MIDDLE CREEK DAM REHABILITATION

EXISTING SPILLWAY REHABILITATION

SEPTEMBER 1984

8M087.113

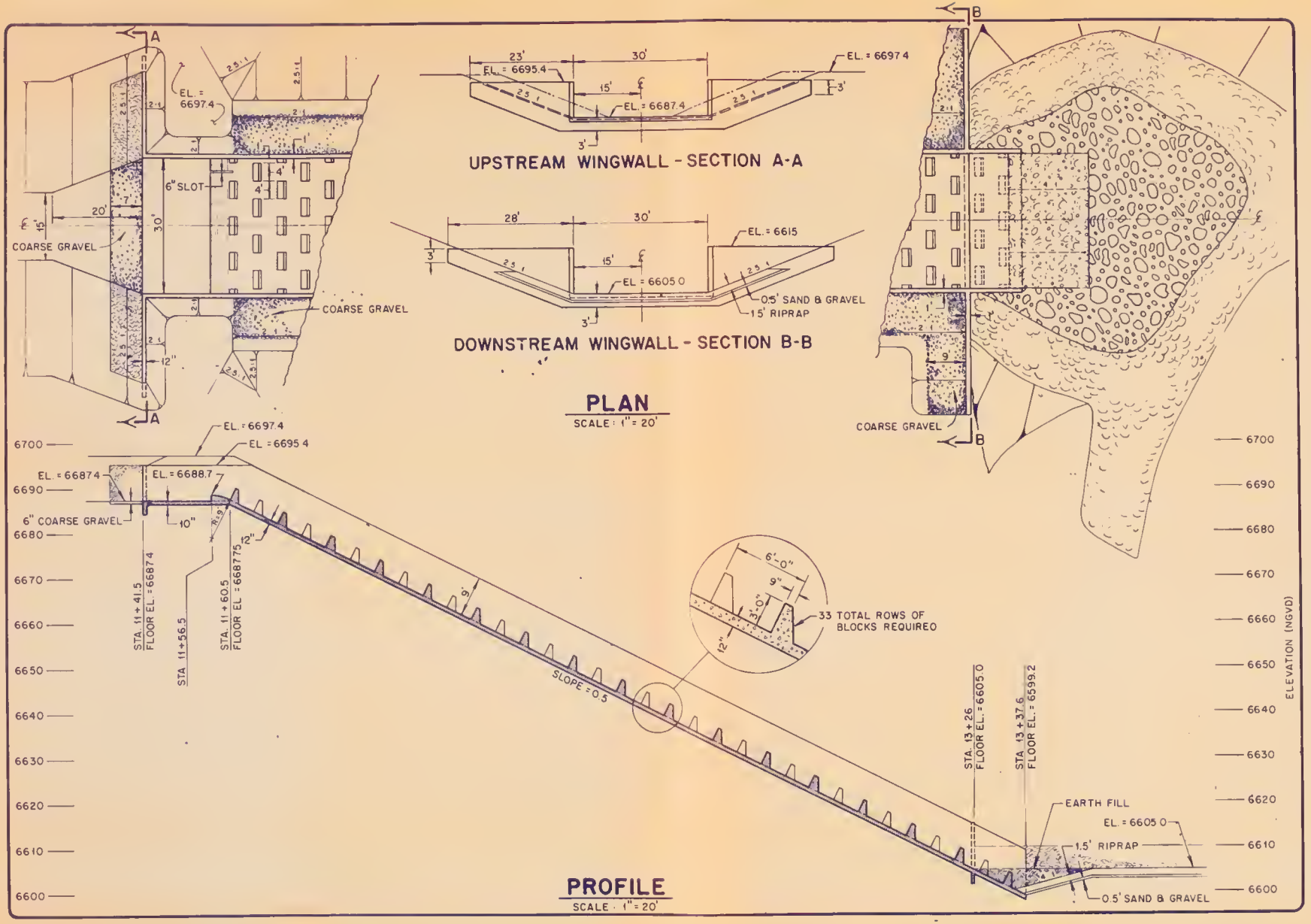


EXHIBIT A-5

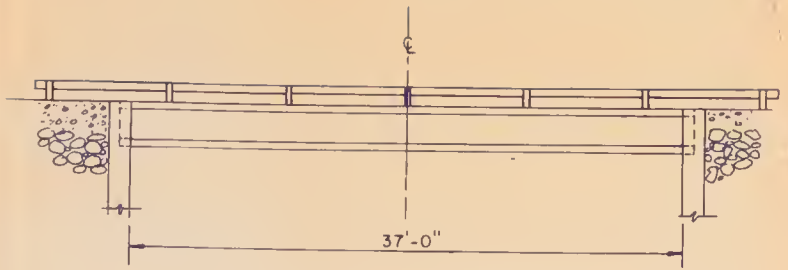
HKM ASSOCIATES
ENGINEERS/PLANNERS

MIDDLE CREEK DAM REHABILITATION

BAFFLED APRON DROP

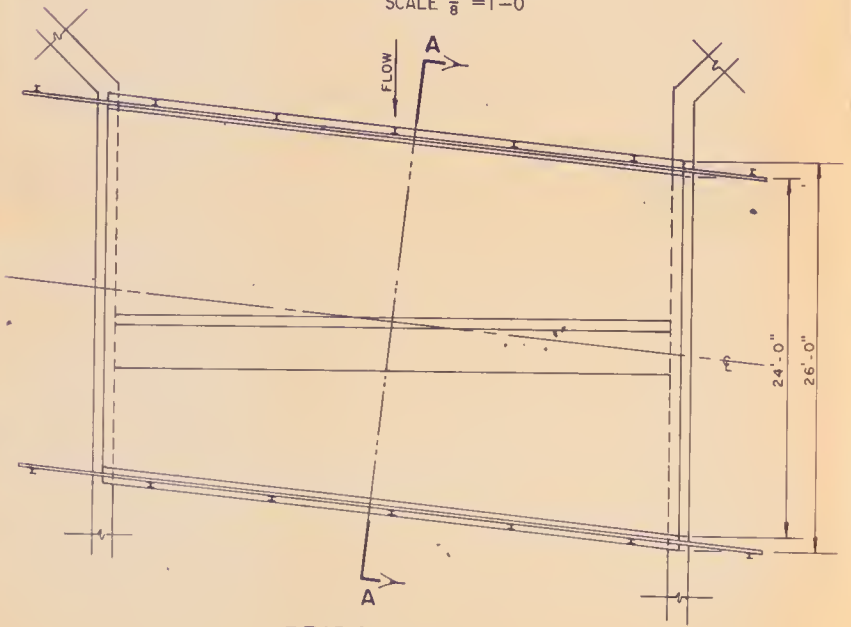
SEPTEMBER 1984

8M087.113



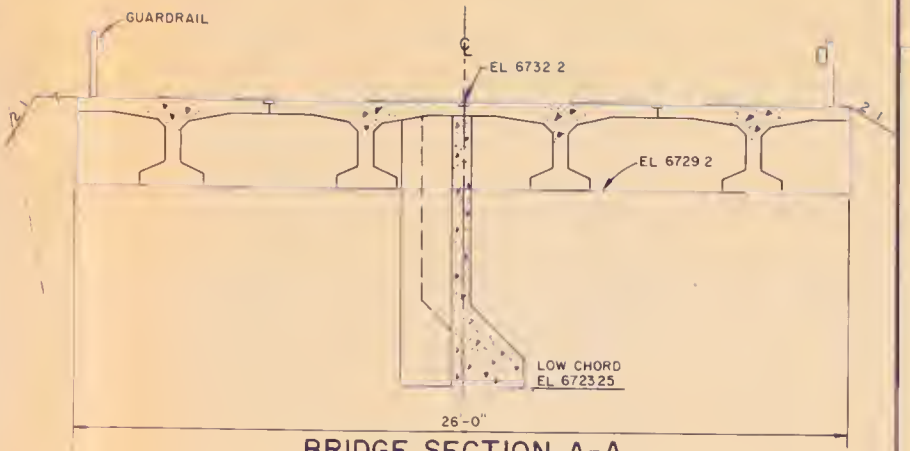
BRIDGE ELEVATION

SCALE $\frac{1}{8}$" = 1'-0"



BRIDGE PLAN

SCALE $\frac{1}{8}$" = 1'-0"



BRIDGE SECTION A-A

SCALE $\frac{1}{4}$" = 1'-0"

EXHIBIT A-6

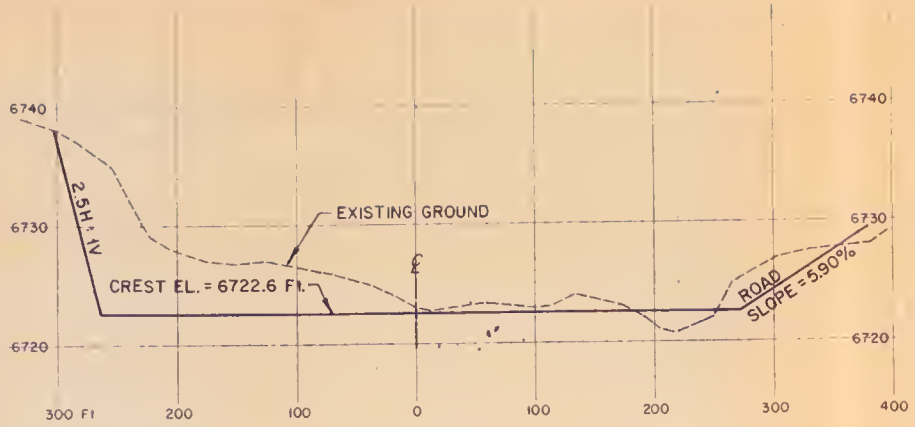
HDR ASSOCIATES
ENGINEERS-PLANNERS

MIDDLE CREEK DAM REHABILITATION

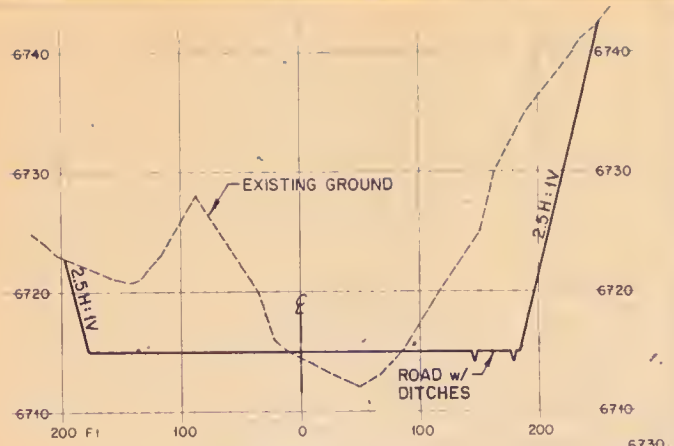
PRINCIPAL SPILLWAY BRIDGE DETAILS

SEPTEMBER 1984

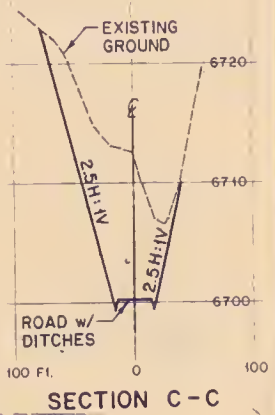
8M087.113



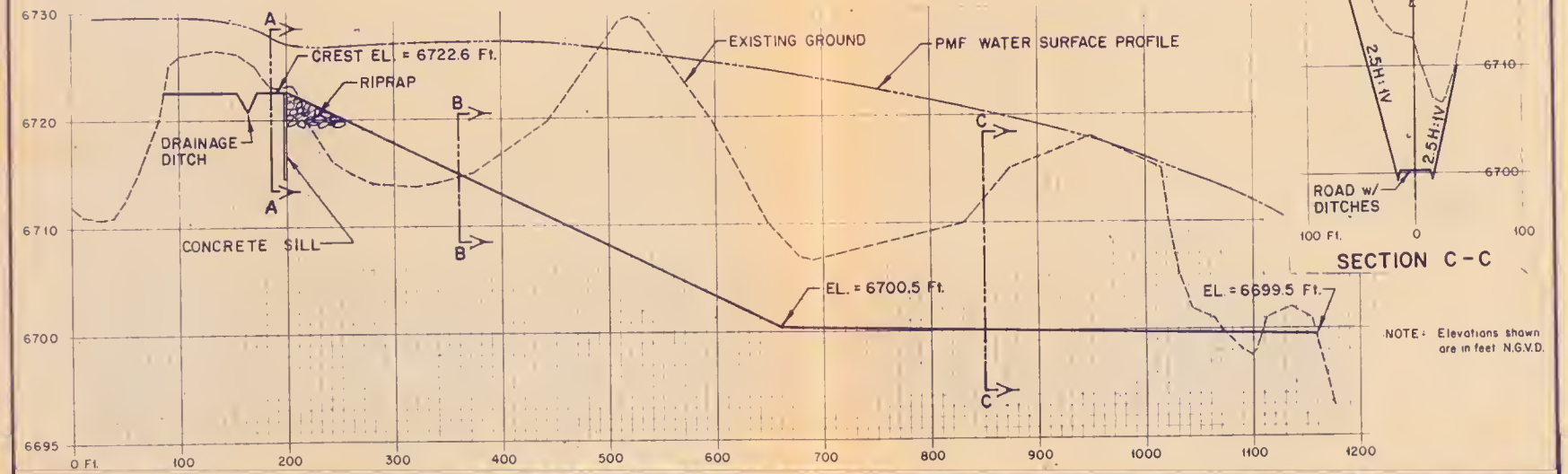
SECTION A-A



SECTION B-B



SECTION C-C



AUXILIARY SPILLWAY PROFILE

NOTE: Elevations shown are in feet N.G.V.D.

EXHIBIT A-7

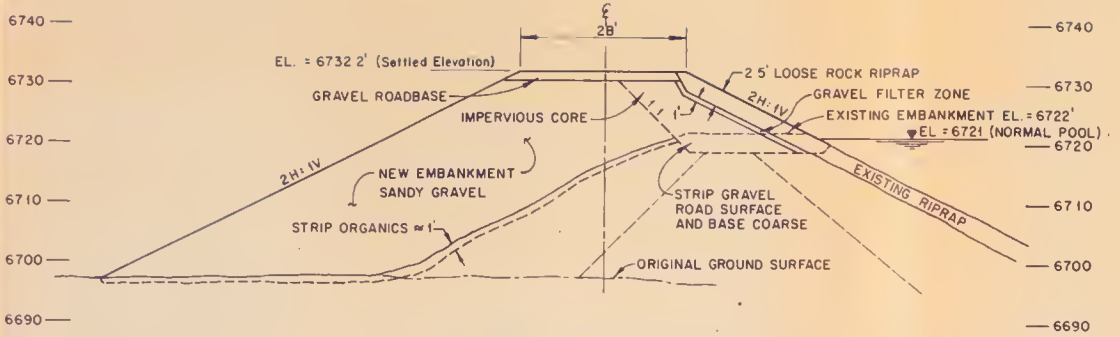
HDR ASSOCIATES
ENGINEERS-PLANNERS

MIDDLE CREEK DAM REHABILITATION

AUXILIARY SPILLWAY PROFILE AND SECTIONS

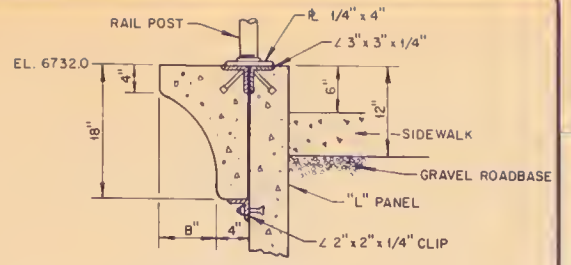
SEPTEMBER 1984

8M067.113



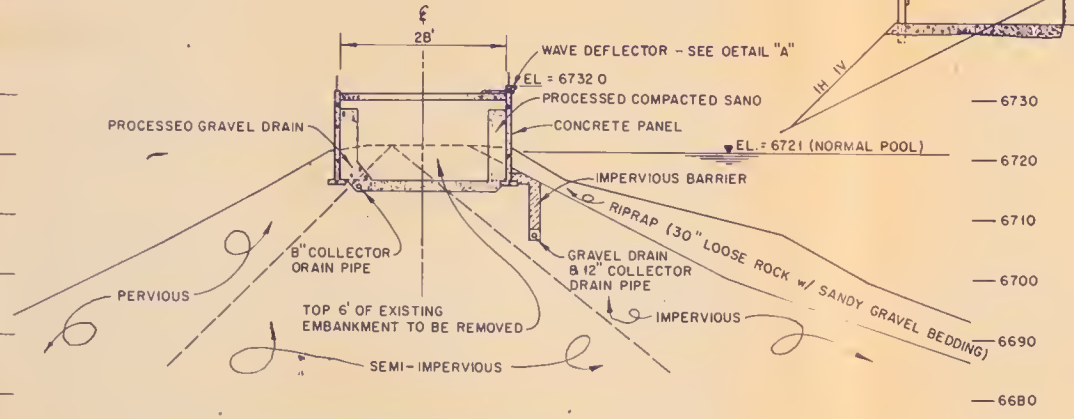
TYPICAL EMBANKMENT SECTION

SCALE : 1" = 20'



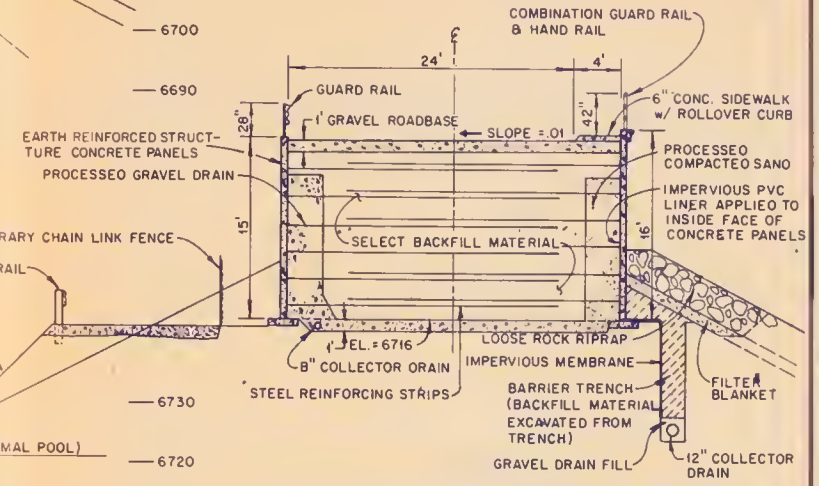
DETAIL "A" WAVE DEFLECTOR

N.T.S.



TYPICAL EARTH REINFORCED STRUCTURE SECTION (AT MAXIMUM SECTION)

SCALE : 1" = 20'



EARTH REINFORCED STRUCTURE SECTION

SCALE : 1" = 10'

EXHIBIT A-8

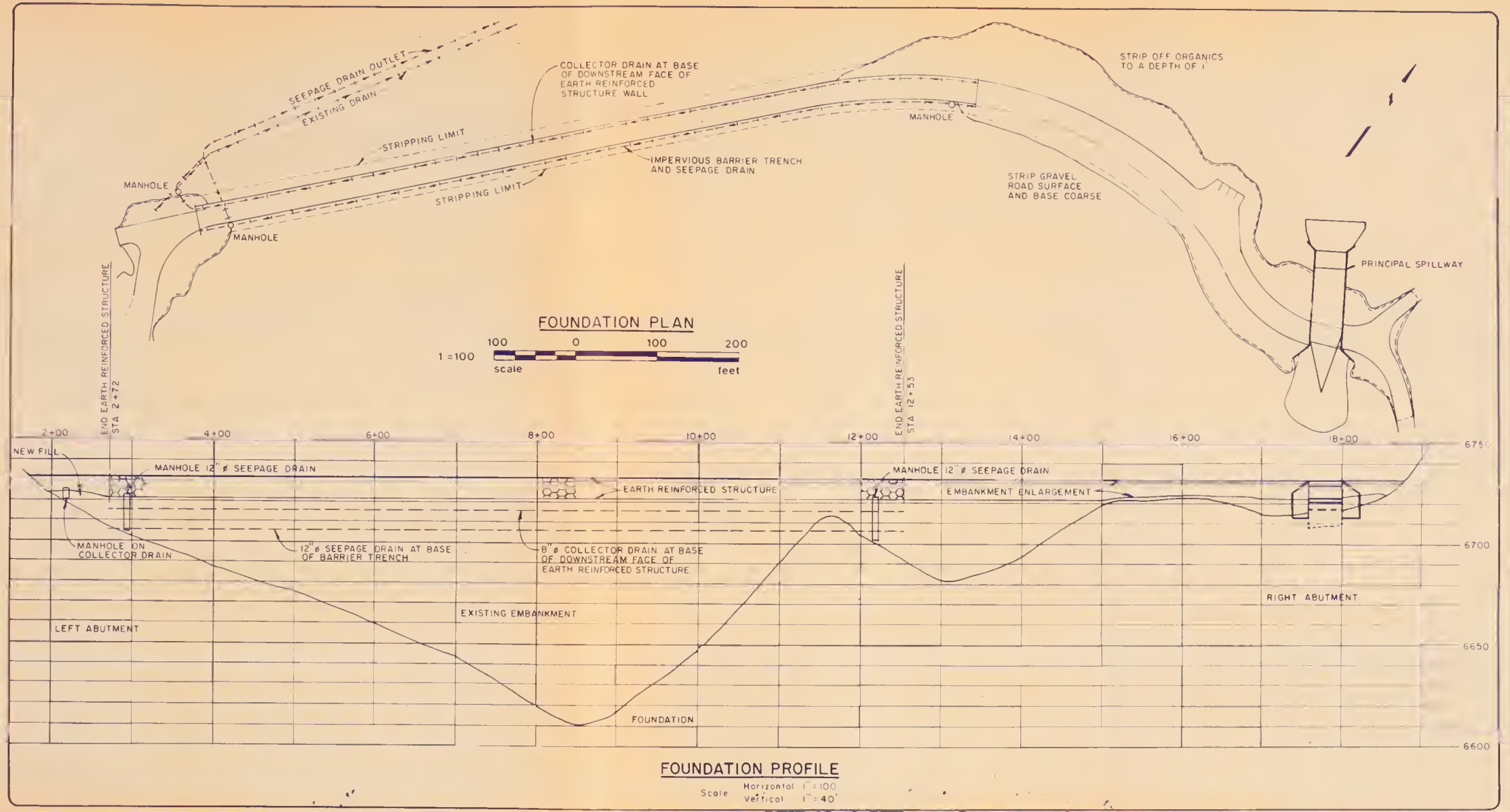
HDR ASSOCIATES ENGINEERS/PLANNERS

MIDDLE CREEK DAM REHABILITATION

EMBANKMENT CROSS SECTIONS

SEPTEMBER 1984

8M087.113



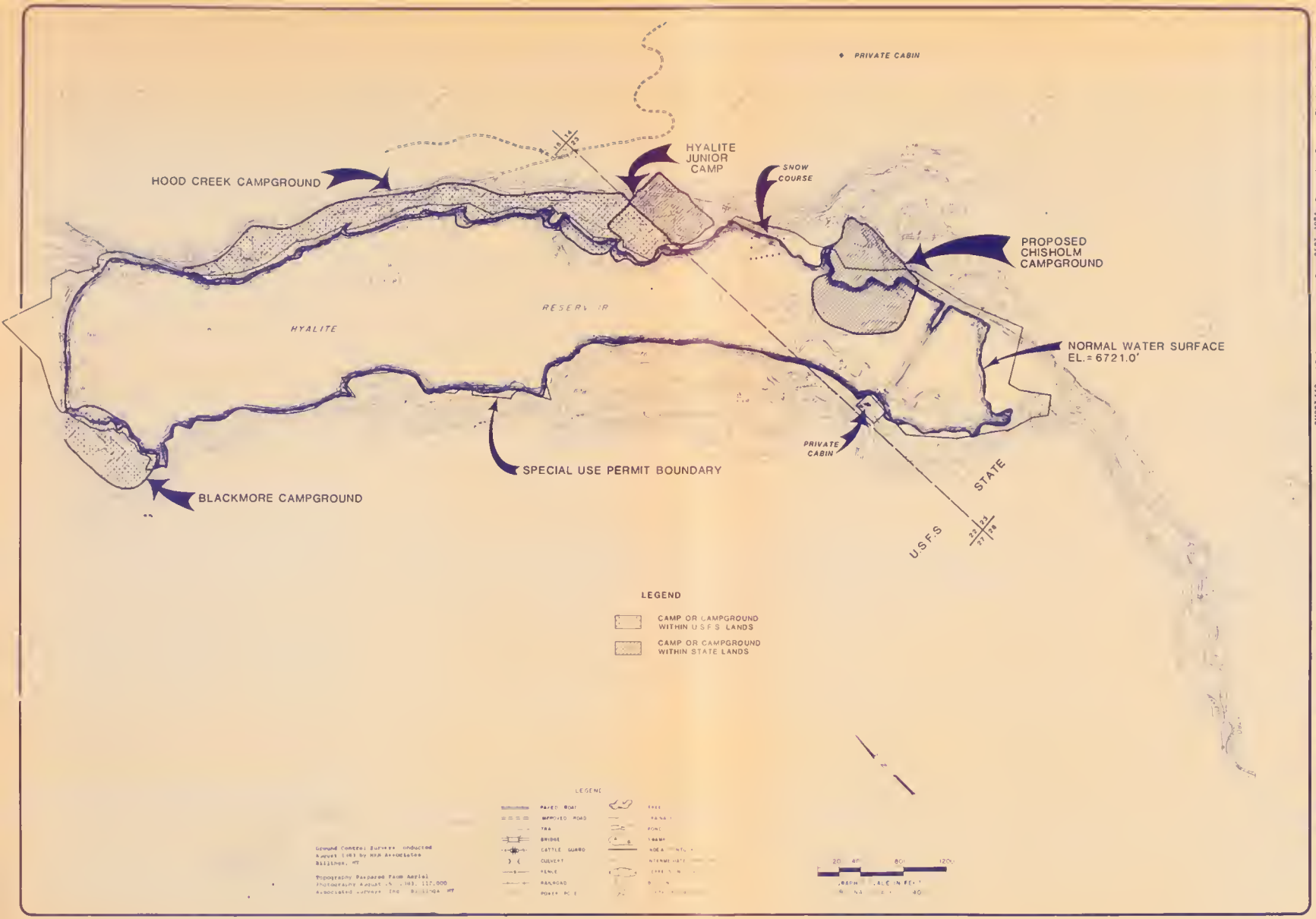
FOUNDATION PROFILE

Scale Horizontal 1" = 100'
Vertical 1" = 40'

EXHIBIT A-9
HEAD ASSOCIATES
CONSULTING ENGINEERS & PLANNERS

MIDDLE CREEK DAM REHABILITATION
FOUNDATION PLAN AND PROFILE
SEPTEMBER 1984

SM087.113



Project No. 84087.113 ID No. Date SEPT. 1984 Designed Drawn Checked Approved

No.	Revision	By	Date

MIDDLE CREEK DAM REHABILITATION

RESERVOIR BASIN MAP

HKM ASSOCIATES
ENGINEERS·ARCHITECTS·PLANNERS
Airport Industrial Park Branch Offices
P O Box 31318 • Libby, Montana
Billings, Montana 59107 • Sheridan, Wyoming

Sheet No
EXHIBIT
A-10
of

EXHIBIT B

FARM BUDGET ANALYSIS

WORKSHEETS

Farm Expenses	Amount	Comments
Purchased Feed	$100.00	See Worksheet L.1
Seed and Establishment Costs	1,327.00	See Worksheet C.1
Twine	1,359.00	See Worksheet C.1
Fertilizer	7,851.00	See Worksheet C.1
Chemicals and Application	1,635.00	See Worksheet C.1
Custom Work	676.00	See Worksheet C.1
Livestock Purchase, Bulls	750.00	See Worksheet L.2
Livestock Expenses	685.00	See Worksheet O.4
Hired Labor, 102 x $3.64/hour	371.00	See Worksheet O.4
Repairs, Buildings and Improvements	1,971.00	See Worksheet O.2
Repairs, Machinery and Equipment	7,328.00	See Worksheet O.3
Depreciation, Buildings	2,464.00	See Worksheet O.2
Depreciation, Machinery	4,836.00	See Worksheet O.3
Fuel, Oil and Lubricants	7,828.00	See Worksheet O.4
Taxes, Land	1,086.00	See Worksheet O.4
Taxes, Cattle	215.00	See Worksheet O.4
Taxes, Other	3,375.00	See Worksheet O.4
Electricity	1,200.00	See Worksheet O.4
Insurance	1,000.00	See Worksheet O.4
Auto Fuel, Oil, Lube and Repairs	1,000.00	See Worksheet O.4
Interest on Operating Capital	1,443.70	See Worksheet O.4
Total, excluding water charges	$48,500.70	
Irrigation Water	300.00	See Worksheet O.4
Total, including water charges	$48,800.70	

Summary of Investment	Total Investment	Interest	Comments
Livestock	31,220.00	1,512.00	Wrksht I.1
Machinery	231,560.00	11,213.00	Wrksht I.2
Buildings and Fences.	98,625.00	1,407.00	Wrksht I.3
Land 1/	111,375.00	1,590.00	Wrksht I.4
Total Investment	472,780.00		
Interest on Investment		15,722.00	

1/ Computed by subtracting the values in Wrksht I.3 from Wrksht I.4.

Net Farm Income Tabulation	Amount	Comments
Crop Sales	60,080.00	See Worksheet C.2
Livestock Sales	20,310.00	See Worksheet L.2
Gross Farm Income	80,390.00	
Farm Expenses	48,500.70	
Interest on Investment	15,722.00	
Total Farm Expenses	64,222.70	
Net Farm Income 2/	16,167.30	

Payment Capacity	subtotal	Amount	Comments
Net Farm Income 3/		22,190.00	
Less:			
Opportunity Cost of Operator			Wrksht O.4
Labor 1/	14,624.00		Wrksht O.4
Equity Allowance	12,857.00		
subtotal		27,481.00	
Payment Capacity 4/			
Total		0.00	
Per Acre (Total Acres) Basis		0.00	

1/ The opportunity cost of operator labor is a proxy for the return to operator and family labor and management. This figure is the average annual gross earning for private nonagriculture work in Montana as reported by the Department of Labor and Industry, Helena, Montana for 1983.

2/ Does not include farm perquisites of $6,023 (HKM).

3/ Includes farm perquisites (HKM).

4/ Calculation of payment capacity results in a negative number. This is equivalent to reducing the equity allowance to $7,566 or $18.92/ acre. The resulting rate of return on equity is 2.1% (HKM).

Total Variable Input Costs WS C.1

	Hay	Winter Wheat	Barley	Pasture	Total
Fertilizer	3,227	979	2,457	1,188	7,851
Custom Spread	338	135	203		676
Seed		276	488		764
Chemicals, 2,4-D		210	315	210	735
Chemicals, Fargo			900		900
Twine	1,359				1,359
Reestablishment	563				563
Total	5,487	1,600	4,363	1,398	12,848

1/ All data are from "Enterprise Costs for Irrigated Crops in Gallatin County," (Cooperative Extension Service Bulletin #1182) and are updated to 1982 prices using "Prices Paid by Farmers Index," as published in Agricultural Statistics, 1982 (USDA, 1983).

Crop Production and Disposal WS C.2

Crop	Acres	Units	Yield per Acre	Total Product	Farm Use	Quantity Sold	Sales Price 1/	Value
Alfalfa-Grass Hay	150	T	3.33	499.50	124.00	375.50	$67.50	25,346
Winter Wheat	60	BU	66.33	3,979.80	0.00	3,979.80	$4.42	17,591
Barley	90	BU	69.33	6,239.70	76.00	6,163.70	$2.70	16,642
Pasture	60	AUM	5.00	300.00	300.00	0.00	11.39	0
Summer Fallow	30							
Aftermath	300	AUM	0.30	90.00	46.00	44.00	11.39	501
Total								60,080

1/ Price data supplied by the Bureau of Reclamation.

Livestock Inventory, Production and Sales WS L.2

Livestock	Beginning Head	Beginning Value	Purchase Head	Purchase Value	Head Born	Head Died	Head Sold	Average Weight	Total Weight	Market Price 1/	Sales Receipts
Cows	50	25,000				1	5	1000	5000	48.30	2,415
Repl Heifers	7	3,220				0	1	750	750	71.43	536
Bulls	2	3,000	0.5	750			0.5	1800	900	60.60	545
Steer Calves					24	1	23	525	12075	87.90	10,614
Heifer Calves					24	1	16	500	8000	77.50	6,200
Total	59	31,220		750							20,310

1/ Price data supplied by the Bureau of Reclamation.

Livestock Investment Costs (Primarily Interest) WS I.1

Item	Amount
Total Livestock Investment	31,220
Non-real Estate Debt:Equity Ratio	32.50%
Debt Portion	10,147
Effective Interest Rate	14.90%
subtotal	1,512
Equity Portion	21,074
Rate of Return to Equity	3.60% *
subtotal	759 *
Total Interest	2,271 *

* Rate of Return to Equity changed to 3.6% by HKM as per information provided by USBR.

Interest on Machinery Investment WS I.2

Item	Amount	
Total Machinery Investment	231,560	
Non-real Estate Debt:Equity Ratio	32.50%	
Debt Portion	75,257	
Effective Interest Rate	14.90%	
subtotal	11,213	
Equity Portion	156,303	
Rate of Return to Equity	3.60%	*
subtotal	5,627	*
Total Interest	16,840	*

* Rate of Return to Equity changed to 3.6% by HKM as per information provided by USBR.

Building and Improvements Interest Cost WS I.3

Item	Amount	
Total Investment	98,625	
Non-real Estate Debt:Equity Ratio	14.40%	
Debt Portion	14,202	
Effective Interest Rate	9.91%	
subtotal	1,407	
Equity Portion	84,423	
Rate of Return to Equity	3.60%	*
subtotal	3,039	*
Total Interest	4,446	*

* Rate of Return to Equity changed to 3.6% by HKM as per information provided by USBR.

Long-Term Real Estate Debt Interest Cost WS I.4

Item	Acres	$/Acre	Total Value	
Cropland	400	525	210,000	
Real Estate Debt:Equity			14.40%	
Debt Portion			30,240	
Effective Interest Rate			9.91%	
subtotal			2,997	
Equity Portion			179,760	
Rate of Return to Equity			3.60%	*
subtotal			6,471	*
Total Interest			9,468	*
Less: Interest on Buildings and Improvements			4,446	*
Total Interest, Land Only			5,022	*

* Rate of Return to Equity changed to 3.6% by HKM as per information provided bu USBR.

Labor Requirements and Distribution of Hours WS 0.1

Item	Acres or Head	Hours per Ac. or per Hd. Man	Machine	Man	Machine	Seasonal Distribution of Man-hours J	F	M	A	M	J	Jl	A	S	O	N	D
Livestock	60	6.3		378	100	35	63	70	40	20	15	15	15	15	25	30	35
Crops:																	
Alfalfa-Grass Hay	150	2.45	2.04	368	306						167		201				
Winter Wheat	60	2.15	1.71	129	103						4	5	14	76			30
Barley	90	2.43	1.48	219	133				104		8		29		19		59
Pasture	60	0.22	0.18	13	11					13							
Summer Fallow	30	0.57	0.46	17	14						8	9					
Irrigation	300	2.00		600							180	300	120				
Labor Hours by Activity:																	
Livestock				378	100	35	63	70	40	20	15	15	15	15	25	30	35
Crop				1,346	566	0	0	0	104	13	367	314	364	76	19	0	89
Miscellaneous				345	82	7	13	14	29	7	76	66	76	18	9	6	25
Total Farm Work				2,069	748	42	76	84	173	40	458	395	455	109	53	36	149
Labor Hours by Worker:																	
Operator				1682		42	76	84	173	40	300	310	311	109	53	36	149
Family				285							100	85	100				
Contract Labor																	
Other Labor				102							58		44				

Source: Original computer data for "Enterprise Costs for Irrigated Crops in Gallatin County," and "Farm Management Data Manual," prepared by Cooperative Extension Service, Montana and Alberta Agriculture, Canada, respectively.

Buildings and Improvements WS 0.2

Item	Original Cost	Inventory Value	Annual Repairs	Annual Depreciation
Grain Storage	8,000	4,800	160	200
Machine Storage and Shop	18,000	10,800	360	450
Barn	8,450	5,070	169	211
Corrals	3,375	2,025	67	84
Water Development	675	405	13	16
Fences	10,125	6,075	202	253
Dwelling	50,000	30,000	1,000	1,250
Total	98,625	59,175	1,971	2,464

Machinery and Equipment WS 0.3

Item	Original Cost	Inventory Value	Annual Repairs	Annual Depreciation
Tractor, Diesel	35,050	21,030	1,591	402
Tractor, Gas	18,130	10,878	80	87
Truck	26,690	16,014	1,956	1,321
Truck, FWD	11,060	6,636	1,081	1,002
Swather	20,080	12,048	244	96
Baler, pto	10,960	6,576	741	453
Bale Wagon, pto	16,000	9,600	684	339
Combine	53,730	32,238	260	257
Drill	8,110	4,866	201	39
Tool Bar	3,400	2,040	57	16
Tandem Disk	5,320	3,192	200	29
Harrow	330	198	4	2
Ditcher	1,020	612	4	6
Ditch Closer	650	390	4	3
Miscellaneous	11,030	6,618	221	53
Automobile	10,000	6,000	n.a.	731
Total	231,560	138,936	7,328	4,836

1/ Repairs for the automobile are included in the estimate of all variable costs.

OTHER MAJOR ASSUMPTIONS TO THE FARM BUDGET ANALYSIS

Crop Budget Assumptions

1. The size of this representative farm is 400 acres. The crop mix and land use is as follows:

150 acres	Alfalfa-Grass Hay
60 acres	Winter Wheat, Gaines
90 acres	Barley
60 acres	Pasture, Subirrigated
30 acres	Summer Fallow
10 acres	Wastage and Home site.

2. Average annual yields and prices for the crops are as follows:

Crop	Units	Yield/A.	Price/Unit
Alfalfa-Grass Hay	Tons	3.3	$67.50
Winter Wheat	Bu.	66.3	4.42
Barley	Bu.	69.3	2.70
Pasture	AUM	5.0	11.39

All yields are three-year simple averages for the years 1980, 1981 and 1982. All prices are Bureau of Reclamation normalized prices for fiscal year 1984.

3. Seeding rates are 60 pounds per acre for winter wheat, 80 pounds per acre for barley.

4. Chemical weed controls include 2,4-D and Fargo only.

5. A mill levy of 265 mills was used for computing taxes on machinery, buildings and land. Land taxes were based on assessed values of $37.05 and $20.51 for crop and pasture land, and grazing land, respectively.

6. Labor costs for hired labor was charged at $3.64 per hour. This rate includes room and board.

7. Machine storage and shop capacity were based on 3,000 square feet valued at $6.00 per square foot; grain storage was based on 10,000 bushels valued at $0.80 per bushel.

8. Total farm insurance was valued at $1,000 per year.

9. Automobile variable costs were based on $0.20 per mile.

10. Fuel, oil and lubricant costs for the tractor, swather and combine were based on 750, 450 and 35 hours, respectively. Diesel and gasoline are priced at $1.13 and $1.24/gallon, respectively.

11. Electricity (utility) costs were estimated to be $1,200.

12. Operator labor was charged at $5.00 per hour and family labor was charged at $3.64 per hour, the same as hired labor.

13. Fertilization rates for the various crops are as follows:

Crop	Nitrogen	Phosphorus
Alfalfa-Grass Hay	17 lbs/A	83 lbs/A
Winter Wheat	68	
Barley	70	50
Pasture	(from farmer survey $20/A)	

The costs for fertilizer are $0.24 and $0.21 for nitrogen and phosphorus (P205), respectively. Application costs are $2.25 per acre.

14. The irrigation costs included assume a flood irrigation system.

Livestock Budget Assumptions

1. The breeding herd consists of 50 cows and 2 bulls.

2. Ten percent of the cow herd is culled yearly. Bulls are replaced on a four-year basis.

3. A 92 percent calf crop (calves weaned/cows wintered) is obtained.

4. The herd is wintered for 180 days on a ration of hay.

5. Marketing weights for the calves are 525 and 500 pounds for steer and heifer calves, respectively.

6. All livestock prices are based on Bureau of Reclamation normalized prices.

7. Other livestock variable costs, including veterinary and medicine, utilities, and marketing are $685. Livestock taxes are $215.

Other Important Assumptions

1. Debt to equity ratios for real estate and non-real estate farm debt were based on statistics provided by Economic Indicators of the Farm Sector, Income and Balance Sheet Statistics, 1982 as published by the USDA for all debt including households. The debt:equity for real estate and nonreal estate were 14.4 and 32.5 percent, respectively.

2. Rates of return to equity were based on statistics provided by Economic Indicators of the Farm Sector, Income and Balance Sheet Statistics, 1982 as published by the USDA. The average rate of return of equity for 1970 through 1982 was 3.8 percent. (Updated to 3.60%)

3. The effective interest rate on operating capital and intermediate term debt is 14.90 percent, a normalized average of Production Credit Association annual average effective interest rates. This figure was supplied by the Bureau of Reclamation.

4. The effective interest rate on long term debt is 9.91 percent, an average effective interest rate for all long term debt outstanding that is held by the Federal Land Bank in Bozeman, Montana.

5. All formulas used in estimating machinery operating and ownership costs are employed in the Montana State University version of the Oklahoma State Crop Budget Generator.

6. Average annual gross earnings for Montana wage and salary employees was used as a proxy for operator and family labor and management in tabulating payment capacity. This assumes that only one family member is gainfully employed outside the household. This figure of $14,624 was reviewed and accepted as reasonable by the Bureau of Reclamation.

7. The analysis shows a positive payment capacity only when no return is paid to equity. In all scenarios examined for this study water payment capacity is generated from the return to equity.

8. Whenever reference is made to the Bureau of Reclamation in study, it refers to the Bureau of Reclamation's Billings, Montana office. the principal contacts have been A. Dickerman, T. Keller and K. Antonson.

Farm Perquisites (Income Equivalents) Contained in Budgets

Dwelling		
Annual Repairs	$1,000	
Depreciation	1,250	
Debt Interest	714	
Return on Equity	1,541	*
One-Half Automobile		
Operation and Repairs	500	
Depreciation	366	
Debt Interest	242	
Return on Equity	121	*
Ten Percent of Pickup Truck		
Repairs	108	
Depreciation	100	
Debt Interest	54	
Return on Equity	27	*
TOTAL	$6,023	*

* Rate of Return to Equity changed to 3.6% by HKM as per information provided by USBR.

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EXHIBIT C

COMPILATION OF WATER PURCHASE CONTRACTS

MIDDLE CREEK PROJECT

WATER PURCHASE CONTRACTS

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
1951	1	Aakjer, Ralph & Nick	25
	2-A-1	Miller, John L.	50
	3	City of Bozeman	500
	4	City of Bozeman	550
	5-A	Kravik, Breta	25
	6-A	Schoenbach, Mary Benepe	30
	6-B	City of Bozeman	20
	7-A	Boylan, Richard J.	50
	8	Boylan, Boyd W.	25
	9-A-1	Bos, David & M.	50
	10	Doney, Frank R.	125
	11-A-1	Dusenberry, George E.	50
	11-A-2	Small Business Administration	50
	12	Dusenberry, Bert L., Jr.	75
	13-A-2	Landoe, H.B.	50
	14-A	Montana State University	100
	15-A-2	City of Bozeman	75
	16-A	MT Ag. Experiment Station	50
	17-A	Hougen, Roger	75
	18	Johnson, Carl G.	25
	19-A-2-A-1	Hume, Jack	100
	19-B-1	Harris, Marguerite K.	17
	19-B-2	Kirk, Charles H.	33
	21	Kessler, E.E.	100
	22	Kurk, Lester J.	25
	23	Kurk, A.J.	20
	24-A-1	Bos, John	50
	25-A-1	Kraft, Glen O.	50
	25-B	Kraft, Glen	50
	26	Kraft, Earl	100
	27-A-1-A-2	Graf, Eugene & G.	50
	27-A-2-A-2	Graf, Eugene & G.	50
	27-A-3	Lindvig, Einar, Regina & Harold	50
	28-A	Caprio, Joseph M. & Marilyn	100
	29	Nash, Jack	50
	30	Pasha, John R.	50
	31-A	Pasha, Mildred L.	50
	32-A	Pasha, Mildred L.	50
	33	Pasha, W.D.	50
	34	Pasha, W.D.	50
	35-A-1	McKean, Ramona	25
	36-A-1	Kraft, Ray	30

WATER PURCHASE CONTRACTS (continued)

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
	36-A-2	Kraft, Walter K.	70
	37	Smith, Stanley K.	50
	38-A-2	Haggerty, Ruth	25
	39-A-1	Derby, James E. & Emma	20
	40-A-1	Kirk, Marguerite	150
	41-A	Montana State University	50
	42-A-1-B	Westlake, George	50
	43-A-1-A-2	Landoe, H.B.	25
	43-A-1-B-2	Cawlfield, Dave R.	12.5
	43-A-2-A	Kraft, Earl & Melva	25
	43-A-2-B	Anderson, Richard & Mary	25
		1951 Subtotal	3652.5
1952	44-A	Hume, Jack	100
	46	Montana State University	300
	47-A-1	Jordan, Robert	25
	47-B	Wend, David and Alice B.	25
	48-A	Clark, Stan L.	50
	49-A-1-A	Campbell, John & P.	35
		1952 Subtotal	535
1953	50-A-1-A	Kirk, Marguerite	30
	50-A-1-B-2	Graff, Robert & H.	10
	51-A	Gallatin County	25
	52-A-2	Anderson, Richard & Mary	25
	52-B-2	Anderson, Richard & Mary	25
	53-A-2	Husemann, Ed	25
	54-A	Jordan, Robert & Mardella	50
	55-A	Bos, John	50
	56-A	Raffety, Lloyd & Mildred	15
	57-A-1	Fellerhoff, John A. & Ella H.	25
	57-A-2	Stenger, Edward & Helen	25
	58-A	White, Edna Tracy	50
	59-A-1	Jordan, Robert & M.	15
	60-A-1-A	Hargrove, Glen	50
	61-A-2	Landoe, H.B.	50
	62-A-1	Miller, Don	50
	63	Boylan, Paul F.	50
	66-A-1	Boyd, J.C.	75
		1953 Subtotal	645

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WATER PURCHASE CONTRACTS (continued)

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
1954	67-A-1-A	Lewis, Yvonne Ellen	50
	68-A	Johnson, C. Glen	25
	69-A	Wolney, David A.	50
	70-A-1-B	City of Bozeman	50
	72	Westlake, Myron M.	50
	73	Bradley, James C.	50
	74-A	City of Bozeman	10
	75-A-1	Westlund, George F. & Nancy J.	50
	76-A-2	Bennett, Marshall a/o Luzann	50
		1954 Subtotal	385
1955	77	Dyk, Peter S.	200
	78	Cawlfield, Dave R.	40
	79	Sapo, Dr. F.	100
	81	Cline, C.E.	50
		Lloyd & Mildred	50
		Lang, Vernon J.	100
	85-A-1	Walker, Edwin	30
	86	Hoppel, Fred G.	20
		1955 Subtotal	590
1956	20-A-1-A	Miller, Don	25
	20-B-1	Dogterom, C.A. and/or McChesney, A.L.	50
	20-C	Wolney, David A.	50
	88	City of Bozeman	1450
	89-A-1-B	City of Bozeman	50
		1956 Subtotal	1625
1958	45-A-1	Lane, Thomas E. & Robert D.	100
	64-A-1	Anderson, Richard & M.	15
	71-A-1	Hume, Jack	50
	83-A-1	Vincent, Tom E. & Marjorie S.	50
	90-A	McCrosson, John W., Jr.	12.5
	91-A	Walker, Edwin & Hilda H.	20
		1958 Subtotal	247.5

WATER PURCHASE CONTRACTS (continued)

MIDDLE CREEK PROJECT

Term = 30 years

First Payment	Contract No.	Purchaser (as of 5-24-83)	Acre Feet
1959	92-A-2	Lee, Clara B.	40
	92-B	Amunrud, Leroy & Dorris	20
		1959 Subtotal	60
1960	93-A	Cattrell, David	20
	95-A	Enger, Lawrence & M.	20
		1960 Subtotal	40
1961	94	Raffety, Lloyd & Mildred	10
		1961 Subtotal	10
1966	96-A	Bennett, Marshall B. and/or Ciluzann	20
		1966 Subtotal	20
		TOTAL CONTRACTS	7,810

Source: Department of Natural Resources and Conservation, Water Projects Accounting System, 0422-Middle Creek Water Users Association.

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EXHIBIT D

GLOSSARY OF TECHNICAL TERMS

EXHIBIT D

GLOSSARY OF TECHNICAL TERMS

500-Year Flood - The flood that can be reasonably expected to exceed once every 500 years.

Alluvium - A general term for all soil deposits resulting from the operation of modern rivers, thus including the sediments laid down in riverbeds, floodplains, lakes, and at the toe of slopes and estuaries.

Auxiliary Spillway - That spillway used very infrequently.

Baffle or Chute Blocks - Structural blocks used to dissipate energy.

Baffled Apron Drop Spillway - A baffled chute used to drop water from one level to another where a stilling basin is undesirable.

Benefit/Cost Ratio - The ratio of economic benefits to the costs over the life of the project.

Consumptive Use - Consumptive use, often called evapotranspiration, is the amount of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from adjacent soil or intercepted precipitation on the plant foliage in any specified time.

Conveyance Efficiency - Ratio of volume of water delivered to farm headgates to the volume of water diverted.

Dissolved Solids - Salts found in dissolved or ionic form in water commonly measured in parts per million.

Dynamic Stability Analysis - An engineering calculation of the resistance of an earth slope to sliding. This calculation considers the dynamic forces on the earth slope induced by seismic activity.

Effective Rainfall - Precipitation falling during the growing period of the crop that is available to meet the consumptive water requirements of crops.

End Sill - Structural component of a stilling basin which dissipates energy.

Farm Perquisites - Income equivalent which are a spin-off from farming including housing and private use of automobiles.

Freeboard - The vertical distance between the top of the dam and the maximum water surface elevation which is provided to protect the dam embankment from overtopping due to wave runup and wind setup.

Gabions - A steel wire cage filled with stones used for soil stabilization.

Growing Season - That period of time in which the crop is growing and consuming water, usually extends from the last killing frost in the spring to the first killing frost in the fall or until the crop reaches maturity.

Induced Infiltration - Infiltration of water from a streambed due to lowering of the water table adjacent to and under the stream.

Irrigation Efficiency - The percentage of applied or diverted irrigation water that is stored in the soil and available for consumptive use by the crop. When the water is measured at the farm headgate, it is called on-farm-irrigation efficiency; when measured at the field, it is designated as field-irrigation efficiency; and when measured at the point of diversion, it may be called project or unit-efficiency.

Jet Pump - A pump which forces a motive fluid through a nozzle creating a low pressure area. This introduces the suction fluid into a diffuser where the high velocity of the jet is changed into pressure.

Labyrith Weir - A sawtooth patterned inlet which allows increased spillway efficiency.

Marginal Value - Goods valued at their cost of production.

Maximum Water Surface Elevation - The maximum reservoir pool elevation attained during routing of the spillway design flood.

National Geodetic Vertical Datum - A national datum which forms the basis for the computation of horizontal survey control in which the curvature of the earth is considered.

Net Irrigation Requirement - The depth of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, that is required consumptively for crop production.

Nonerodible Velocity - The greatest mean velocity which will not cause erosion of a channel.

Normal Water Surface Elevation - The reservoir pool elevation corresponding with the top of the active storage pool (the portion of storage used to supply agricultural and municipal needs).

Normalized Prices - Agricultural commodity prices which are adjusted statistically to minimize the effect of price fluctuations and localized market differences.

Ogee Crest - A spillway crest which is Ogee or s-shaped in profile and allows high discharge efficiency.

Overland Flows - The component of runoff which travels overland.

PVC - Poly Vinyl Chloride.

Payment Capacity - The ability to pay for the annual costs of irrigation after considering farm expenses, interest on indebtedness and allowable returns to ownership.

Phreatic Water Surface - A phreatic surface develops within a soil mass which is at least partially saturated. This surface is the location at which the pore water pressure is atmospheric. A similar term denoting approximately the same location is water table.

Present Value - Value at time = 0 of the amount earned if invested at the given interest rate uniformly over a given period.

Prestressed Concrete - Precast, structural elements in which reinforcing is provided by high strength steel which is pretensioned.

Principal Spillway - That spillway used frequently on a year-to-year basis.

Probable Maximum Flood - The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region.

Producer Surplus - The increased economic value of a commodity over that actually paid.

Reinforced Earth - A patented system of retaining wall construction. Retaining walls are formed with concrete panels supported by steel reinforcing straps extending from the panel horizontally into the wall backfill.

Returns to Equity - An opportunity cost partially offsetting the return if the equity funds were invested at the going interest rate.

Returns to Labor - That portion of net farm income allocated to the owner and his family for their labor.

Returns to Management - A return allowed for the additional expertise to own and operate a business.

Right and Left Abutments - The abutments are the natural valley walls into which the embankment abuts. The right and left convention is determined by looking downstream.

Riprap - A wall or zone of material usually composed of loose rock massed together to provide resistance to erosion caused by the movement of water.

River Basin Efficiency - Ratio of water consumed by crops, non-beneficial vegetation and water returning outside of growing season to that volume of water diverted less recoverable return flows.

Service Area - The gross area to which water can be delivered.

Sinking Fund Depreciation - A uniform amount invested each year at a given interest rate which will repurchase the item at the end of its life less salvage value.

Specific Yield - The quantity of water that a unit volume of sand or gravel will give up when drained by gravity.

Spillway Design Flood - The largest flood that need be considered in the evaluation of a given project.

Static Stability - An engineering calculation of the resistance of an earth slope to sliding. This calculation considers the physical and engineering properties of the materials involved. The driving force (causing sliding) is the static weight of the soil.

Tailrace - The channel downstream of a hydraulic structure.

Transmissivity - Rate of flow in gallons per day through a vertical section of an aquifer whose height is the thickness of the aquifer and whose width is one foot with a hydraulic gradient of 1.0.

Wave Runup - Vertical height above the stillwater level that water reaches because of waves.

Wind Setup - The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water.

EXHIBIT E

SPILLWAY HYDRAULICS

EXHIBIT E
SPILLWAY HYDRAULICS

PRINCIPAL SPILLWAY

The principal spillway has five major components, as shown on Exhibits A-1, A-3, A-4, and A-5. These are the inlet, chute, stilling basin, channel, and baffled apron drop. The hydraulic analysis of each will be discussed briefly in the following paragraphs.

Inlet

The crest was designed as a one cycle labyrinth weir using the method outlined in Hay and Taylor, "Performance and Design of Labyrinth Weirs", ASCE J. Hyd. Div., November 1970. The 143-foot long crest provides 3.86 times the weir length of a straight weir within the chute. The crest is trapezoidal in cross section with a 3H:1V sloping upstream face and vertical downstream face. For this slope of weir, Brater-King, Handbook of Hydraulics, 6th Edition, McGraw Hill, 1976, gives a relatively constant discharge coefficient of 3.57. The height of the weir above the upstream base (P) is 13.3 feet. The resulting unsubmerged rating curve over the weir had flows between 3.00 and 4.02 times the discharge of a straight sharp crested weir across the inlet.

The downstream apron was located 4 feet below the crest to cause submergence for flows greater than the 500-year routed peak of 1,000 cfs. Downstream water surface profiles were analyzed using step backwater computations beginning at critical depth a distance of three times the critical depth upstream of the vertical curve. For this section a slope of 0.0 and a Manning's "n" of 0.015 were used. Submergence of the weir was computed by energy balance across the submerged weir,

assuming a headloss of 0.2 times the difference in velocity head between the reservoir and a section at the downstream apexes of the labyrinth.

Flow entering the principal spillway during the PMF is restricted by an orifice wall extending down from the center of the bridge. During the 500-year flood, the wall maintains a freeboard of 3 feet above the water surface in the inlet for wave clearance. During the PMF, however, the orifice is activated to limit flows to 3,400 cfs, thereby reducing the required chute and stilling basin capacity.

Chute

The vertical curve and chute section were designed using guidelines given in USBR, Design of Small Dams, 2nd Edition, Revised 1977. The vertical curve was designed for the maximum flow of 3,400 cfs to avoid structural damage during the PMF. Freeboard, however, was based on the design flow of 1,000 cfs. Wall heights through the section were selected as the greater of the PMF water surface and the 500-year water surface plus freeboard. It was felt that minor damage due to wave overtopping was acceptable during the PMF. The water surface profiles through this section were approximated by using gradually varied flow with a Mannings' "n" of 0.008, as recommended by SCS, Engineering Handbook Section 14, Chute Spillways, Revised October 1977, beginning with critical depth at the entrance to the vertical curve.

Stilling Basin

The stilling basin was designed as a USBR Basin III, using criteria given in USBR, Hydraulic Design of Stilling Basins and Energy Dissipators, EM #25, 1978, for a design flow of 1,000 cfs. Stilling basin wall heights were checked for overtopping during the PMF and found to be satisfactory. Low tailwater

during the PMF would cause the hydraulic jump to sweep out of the stilling basin, causing some possible damage from undermining. Due to the remoteness of the PMF and the slow acting destruction from undermining of the downstream end, it is felt that this damage is acceptable.

Tailwater was modeled using COE, Generalized Computer Program HEC-2, Water Surface Profiles, Davis, CA, September 1982. The floor elevation was set based on full conjugate depth for the design flow of 1,000 cfs. Lower flows were checked to assure that stilling action would be effective for all flows less than design flow.

Riprap beyond the stilling basin was designed using criteria given in USBR, Design of Small Canal Structures, 1978, for chute outlet protection.

Channel

The channel was designed to minimize earthwork and prevent erosion up to the rated flow of 1,000 cfs. The inlet sill elevation to the baffled apron drop was varied to keep velocities in the channel below 5 fps. Since the highest velocities occur in the 200 feet just downstream of the stilling basin and large excavations in that area are undesirable, the baffled apron inlet sill was located above the lowest point in the channel. An adverse slope exists between the meadow and baffled apron inlet. Drainage in this section will be accounted for in final design.

The dike across the meadow is designed to overtop during floods greater than the design flood. This minimizes the required capacity of the baffled apron drop. The top of the dike was therefore placed at the computed 500-year water surface. The PMF water surface profile was computed using the HEC-2 split

flow routine. It was assumed that the dike would remain intact for conservative design of the baffled apron drop. Manning's "n" values were taken from Chow, Open Channel Hydraulics, McGraw Hill, 1959, and ranged from 0.04 for high retardance grassed channels to 0.1 for trees and brush on the side slopes.

Baffled Apron Drop

The baffled apron drop was designed using techniques found in USBR, EM #25. A design flow per unit width of 35 cfs per foot was chosen. From the HEC-2 split flow analysis it was determined that a maximum discharge of 1,500 cfs would enter the baffled apron drop during the PMF, giving a unit discharge of 50 cfs per foot, which is less than the maximum allowable 60 cfs per foot. The inlet apron was designed to give a maximum 5 fps velocity during the 500-year flood. Wall height at the inlet was chosen to extend slightly above the water surface during the PMF.

Inlet and outlet riprap were selected using the USBR, Design of Small Canals criteria for chute outlet protection. It can be seen from Exhibit A-1 that water exiting the baffled apron drop must make a sharp bend to intersect the channel. It is probable that large eddies will form in the tailwater area. Riprap is therefore specified on all slopes in the affected areas. This will also provide protection for the outlet works.

The water surface profile for the peak flow occurring during the routed 500-year flood is plotted on Exhibit A-3.

AUXILIARY SPILLWAY

The auxiliary spillway was designed to safely pass the PMF, minimize environmental impact, and minimize excavation. The hydraulic design was performed using COE and USBR criteria, and checked using HEC-2.

An excavation and dike downstream of the existing reservoir access road were necessary to direct the flood away from the toe of the dam. The depth and width of cut were selected to fit the existing topography and carry the flow within natural banks at the most downstream excavation. The top of the dike follows the energy grade line of the maximum routed PMF flow, as computed with HEC-2. Since the maximum velocity along the dike was computed to be 12.3 fps a layer of 22 inch (nominal diameter) riprap was specified on the exposed face, as recommended by USBR EM #25.

For all flows less than the design flow, critical depth occurs where the channel crosses the existing reservoir access road.

Since raising the dam 10 feet would necessitate a 8.6% grade on the access road between the auxiliary spillway crossing and the dam, it was decided to route the access road up the auxiliary spillway. Using a 24-foot road bed with 2-foot shoulders and 4-1/2-foot wide drainage ditches on both sides gives a minimum channel bottom width of 37 feet. Due to the shape of the drainage that the auxiliary spillway follows, a deep, narrow excavation will require less excavation than a wide shallow excavation. For this reason, a channel with the minimum bottom width was chosen for as much of the spillway as possible.

The crest of the spillway was chosen to be circular in plan to fit the terrain, provide aesthetic appeal, and provide smooth transition to the narrow channel. The crest elevation was chosen to be equal to the 500-year peak reservoir water surface elevation. The length of the crest was chosen using HEC-2 beginning with critical depth at the crest and ending with a still pool energy grade line equal to the maximum water surface elevation for the peak routed PMF outflow.

The transition from the crest to the channel was designed using USBR, Design of Small Dams convergence criteria based on Froude number. The elevations of the end of transition invert and the end of channel invert were found by iteration. It was found that a minimum slope in the channel section caused by a one-foot drop over its length would provide adequate drainage, maximize hydraulic efficiency, and minimize excavation. The end of transition invert elevation was then varied in HEC-2 until the depth at the crest was critical for the minimum flow. The length of transition was adjusted in each iteration to account for the changes in Froude numbers at the transition end points. A Manning roughness coefficient of 0.04, expansion coefficient of 0.5, contraction coefficient of 0.3 and side slopes of 2.5H:1V were used for the entire spillway.

The effect of log jamming at the end of the transition was investigated. It was found that by placing a 5-foot high obstruction across the bottom of the channel, the reservoir water surface would rise to within 0.15 feet of the top of the dam at peak PMF discharge. Since the spillway flow at the point of obstruction would have a channel velocity of 23.6 fps, a depth of 23.9 feet, and a top width of 131 feet, the erosive power of the water in that section would be tremendous. Even if a log jam could withstand the tremendous static and dynamic forces, it is doubtful that its foundation would. For these reasons, it is felt that debris will not be a problem in this spillway.

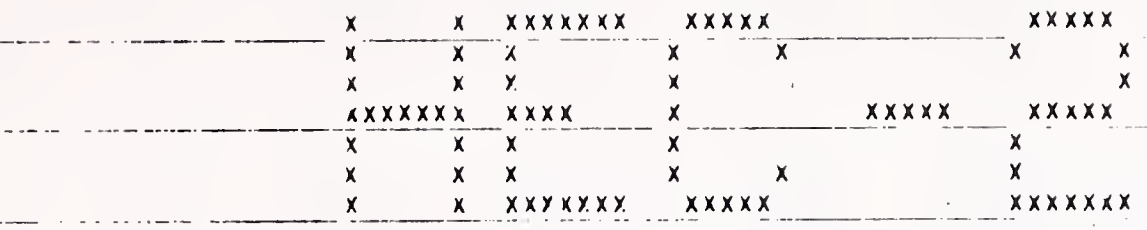
The plan view of this spillway is shown in Exhibit A-1. The profile with the maximum flow water surface profile is shown in Exhibit A-7.

EXHIBIT F

FLOOD ROUTING STUDIES

```
*****************************************
*  WATER SURFACE PROFILES               *
*  VERSION OF NOVEMBER 1975             *
*  UPDATED MARCH 1982                   *
*                                       *
*  RUN DATE  7/23/84                    *
*****************************************
```


```
*****************************************
*  U.S. ARMY CORPS OF ENGINEERS         *
*  THE HYDROLOGIC ENGINEERING CENTER    *
*  609 SECOND STREET, SUITE D           *
*  DAVIS, CALIFORNIA 95616              *
*    (916) 440-2105 (FTS) 448-2105      *
*****************************************
```

THIS RUN EXECUTED 7/20/84

[illegible]
ERROR CODE = 01,02,03,0,0,0
MODIFICATION = 00,01,02,03,04,05

T1 MIDDLE CREEK DAM
T2 AUXILIARY SPILLWAY - OPTION 3B, WITH CRITICAL DEPTH AT SEC. 1140
T3 HKM ASSOCIATES - 7/84

J1	ICHECK	INV	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	0.	0.	0.	-1.000000	0.0	0.0	29030.	6715.000	0.0

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLOC	IBW	CHNIM	ITRACE
	-1.000	0.0	0.0	0.0	0.0	0.0	-1.000	0.0	0.0	0.0

NC	0.040	0.040	0.040	0.100	0.500	0.0	0.0	0.0	0.0	0.0
X1	1140.000	4.000	100.000	160.000	0.0	0.0	0.0	0.0	-1.000	0.0
GR	6715.000	0.0	6700.500	100.000	6700.500	160.000	6715.000	220.000	0.0	0.0
X1	972.000	9.000	47.300	84.300	165.000	168.000	168.000	0.0	-0.510	0.0
GR	6720.000	0.0	6700.379	47.300	6700.379	84.300	6705.000	96.400	6720.000	121.400
X1	833.000	4.000	75.000	112.000	307.000	242.000	287.000	0.0	10.500	0.0
GR	6720.000	0.0	6693.000	75.000	6693.000	112.000	6720.000	187.000	0.0	0.0
X1	705.000	4.000	44.000	327.500	285.000	224.000	230.000	0.0	-0.750	0.0
GR	6730.000	0.0	6712.297	44.000	6712.297	327.500	6730.000	371.500	0.0	0.0
X1	300.000	4.000	19.000	549.000	230.000	230.000	230.000	0.0	0.0	0.0
GR	6730.000	0.0	6722.598	19.000	6722.598	549.000	6730.000	567.000	0.0	0.0
X1	250.000	0.0	0.0	0.0	20.000	20.000	20.000	0.0	0.0	0.0
NC	0.040	0.040	0.040	0.100	0.300	0.0	0.0	0.0	0.0	0.0
X1	100.000	20.000	-91.000	552.000	180.000	180.000	180.000	0.0	0.0	0.0
GR	6730.000	-140.000	6722.598	-91.000	6722.598	145.000	6710.000	237.000	6710.000	337.000
GR	6702.000	440.000	6702.000	552.000	6705.000	702.000	6715.000	797.000	6730.000	952.000
EJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Auxiliary Spillway - 7/20/84
Option 3E w/road in spillway, 10 day

$b_{crest} = 530'$
$L_{Trans} = 460'$
Invert $El_{end\ of\ Trans} = 6699.5'$
Invert Elend Channel = 6700.5'
$Q_{Aux} = 29030\ cfs$

Option 3E, 7/20/84
Adjustment for flood in Aux. Spillway and decreased prim. spillway capacity, (with orifice)
Input THEC2SF9

Option 20 - w/ real in-spillway orifice

Input - J HEC2SP4

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

#PROF 1

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV= 0.300 CEHV= 0.300
#SECNO 1140.000
3720 CRITICAL DEPTH ASSUMED

1140.00	13.63	6713.13	6713.13	6715.00	6717.65	4.52	0.0	0.0	6699.50
29030.	7989.	15306.	4736.	640.	913.	334.	0.	0.	6699.50
0.0	12.46	19.95	12.33	0.040	0.040	0.040	0.0	6690.50	6.03
0.008657	0.	0.	0.	0	11	0	0.0	210.34	216.38

#SECNO 972.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

972.00	14.20	6719.07	6714.07	0.0	6725.91	6.45	1.39	0.96	6699.87
29030.	6819.	15711.	6900.	449.	710.	373.	7.	1.	6699.87
0.00	14.07	23.52	15.09	0.040	0.040	0.040	0.0	6699.87	1.33
0.007793	166.	168.	161.	0	11	0	0.0	119.67	120.70

#SECNO 633.000

3301 HV CHANGED MORE THAN HVINS

633.00	24.51	6725.11	6714.29	0.0	6727.30	2.69	1.17	1.13	6700.50
29030.	7247.	14830.	7247.	757.	910.	757.	19.	2.	6700.50
0.01	9.58	15.77	9.58	0.040	0.040	0.040	0.0	6700.50	13.50
0.002582	307.	237.	242.	4	5	0	0.0	160.00	173.50

$F_2 = \frac{29030}{2424\sqrt{5\frac{2424}{160}}} = .54$

$I_T = (557-160)(.20)(1.54) = 439'$ OK ✓

#SECNO 466.000

3301 HV CHANGED MORE THAN HVINS

466.00	15.70	6726.24	6713.33	0.0	6723.71	0.47	0.24	0.67	6711.55
29030.	1171.	25638.	1171.	347.	4735.	347.	41.	3.	6711.55
0.02	3.38	5.64	3.38	0.040	0.040	0.040	0.0	6711.55	2.48
0.000539	285.	230.	224.	2	14	0	0.0	356.53	369.02

SECNO	DEPTH	CNSTL	CRIWS	WSELK	EG	HV	HL	QLOSS	BANK ELEV
Q	VLOB	VCH	VROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IOC	ICONT	CORAR	TOPWID	ENDST

*SECNO 300.000

3301 HV CHANGED MORE THAN 4VINS

300.00	5.42	6728.02	6727.09	0.0	6729.54	1.52	0.31	0.53	6722.60
29030.	225.	23591.	213.	38.	2875.	36.	63.	5.	6722.60
0.03	3.98	3.94	5.95	0.040	0.040	0.040	0.0	6722.60	5.08
0.007517	230.	230.	230.	3	14	0	0.0	557.11	562.19

*SECNO 230.000

230.00	5.32	6729.41	6727.09	0.0	6729.73	1.32	0.13	0.06	6722.60
29030.	242.	23550.	223.	43.	3080.	41.	64.	6.	6722.60
0.03	5.68	9.27	5.55	0.040	0.040	0.040	0.0	6722.60	4.08
0.005761	20.	20.	20.	3	11	0	0.0	559.05	563.13

CCHV= 3.100 CEHV= 0.300

*SECNO 100.000

3301 HV CHANGED MORE THAN 4VINS

100.00	27.44	6729.84	6701.54	0.0	6729.89	0.05	0.03	0.13	6722.50
29030.	37.	17197.	21795.	57.	10782.	5976.	105.	9.	6702.00
0.03	0.55	1.59	1.37	0.040	0.040	0.040	0.0	6702.00	-109.59
0.000344	180.	180.	180.	2	11	0	0.0	560.99	551.41

THIS RUN EXECUTED 7/20/84

****
HEC2 RELEASE DATED NOV 79 UPDATED MAR 1982
ERROR CORR - 01,02,03,04,05
MODIFICATION - 50,51,52,53,54,55
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

MKM ASSOCIATES - 7/84

SUMMARY PRINTOUT TABLE 150

	SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10K*S	VCH	AREA	.01K
*	1140.000	0.0	0.0	0.0	6699.50	29030.00	6713.13	6713.13	6717.64	88.57	13.35	1341.72	3034.59
*	972.000	168.00	0.0	0.0	6693.37	29030.00	6719.07	6719.07	6725.51	77.98	23.52	1532.49	3237.49
	633.000	297.00	0.0	0.0	6700.50	29030.00	6725.11	6719.29	6727.80	25.92	15.97	2423.55	5712.69
	456.000	250.00	0.0	0.0	6711.55	29030.00	6728.24	6718.33	6723.71	5.39	5.54	5423.37	12505.52
	306.000	230.00	0.0	0.0	6722.50	29030.00	6728.02	6727.09	6729.54	75.17	9.34	2943.51	3348.25
	230.000	20.00	0.0	0.0	6722.50	29030.00	6723.41	6727.09	6729.73	59.61	9.27	3164.54	3759.87
	100.000	130.00	0.0	0.0	6702.00	29030.00	6729.34	6709.54	6729.89	0.44	1.59	18325.54	43798.01

HKM ASSOCIATES - 7/84

SUMMARY PRINTOUT TABLE 130

	SECNO	Q	CWSEL	DIFXSP	DIFWSX	DIFKWS	TOPWID	XLCH
*	1140.000	29030.00	6717.13	0.0	0.0	-1.38	210.34	0.0
*	972.000	29030.00	6714.07	0.0	5.94	0.0	119.67	169.00
	835.000	29030.00	6725.11	0.0	5.04	0.0	160.00	287.00
	456.000	29030.00	6723.24	0.0	3.13	0.0	366.53	230.00
	300.000	29030.00	6723.02	0.0	-0.22	0.0	957.11	230.00
	280.000	29030.00	6723.41	0.0	0.39	0.0	559.05	20.00
	100.000	29030.00	6723.34	0.0	1.43	0.0	960.99	180.00

```
**********************************************************
*  WATER SURFACE PROFILES                                *
*  VERSION OF NOVEMBER 1976                              *
*  UPDATED MARCH 1982                                    *
*                                                        *
*  RUN DATE  1/10/85                                     *
**********************************************************
```


```
****************************************
*  U.S. ARMY CORPS OF ENGINEERS        *
*  THE HYDROLOGIC ENGINEERING CENTER   *
*  609 SECOND STREET, SUITE D          *
*  DAVIS, CALIFORNIA 95616             *
*    (916) 440-2105 (FTS) 448-2105     *
****************************************
```


```
X      X  XXXXXXX   XXXXX              XXXXX
X      X  X         X     X           X     X
X      X  X         X                       X
XXXXXXX   XXXX      X         XXXXX     XXXXX
X      X  X         X                   X
X      X  X         X     X             X
X      X  XXXXXXX   XXXXX               XXXXXXX
```

Results:
At peak PMF., log jam infringes on freeboard but does not overtop dam.

HEC-2 Output 1/10/85
Auxiliary Spillway Rating Curve
Option 3B w/road in spillway and orifice controlled principal spillway; USER structures
Test for 5' high log jam @ Section 63
Input: HEC-2 (version 4.6)

Input = IHEC2S19 (temporary change)

THIS RUN EXECUTED 1/10/85

```
**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MAR  1982
  ERROR CORR -  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
**************************************************

T1       MIDDLE CREEK DAM
T2       AUXILIARY SPILLWAY - OPTION 38 WITH OBSTRUCTIONS RATING CURVE,Q=5000CFS
T3       HKM ASSOCIATES - 1/85

J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ
       0.       0.        0.        0. -1.000000       0.0       0.0    5000.  6715.000     0.0

J2  NPROF      IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE
     1.000      0.0       0.0       0.0       0.0       0.0     -1.000      0.0       0.0       0.0

 NC     0.040     0.040     0.040     0.300     0.500     0.0       0.0       0.0       0.0       0.0
 X1  1140.000     4.000   100.000   160.000     0.0       0.0       0.0       0.0     -2.000      0.0
 GR  6715.000     0.0    6700.500   100.000  6700.500   160.000  6715.000  220.000     0.0       0.0

 X1   972.000     5.000    47.800    84.800   168.000   168.000   168.000     0.0     -1.510      0.0
 GR  6720.000     0.0    6700.379    47.800  6700.379    84.800  6705.000   96.400  6720.000   121.400

 X1   653.000     4.000    75.000   112.000   287.000   222.000   267.000     0.0      9.500      0.0
 GR  6720.000     0.0    6690.000    75.000  6690.000   112.000  6720.000  187.000     0.0       0.0

 X1   643.000     0.0       0.0       0.0      10.000    10.000    10.000     0.0      5.000      0.0

 X1   633.000     0.0       0.0       0.0      10.000    10.000    10.000     0.0     -5.000      0.0

 X1   466.000     4.000    44.000   327.500   285.000   224.000   230.000     0.0     -1.250      0.0
 GR  6730.000     0.0    6712.297    44.000  6712.297   327.500  6730.000  371.500     0.0       0.0

 X1   300.000     4.000    19.000   549.000   230.000   230.000   230.000     0.0      0.0       0.0
 GR  6730.000     0.0    6722.598    19.000  6722.598   549.000  6730.000  567.000     0.0       0.0

 X1   280.000     0.0       0.0       0.0      20.000    20.000    20.000     0.0      0.0       0.0

 NC     0.040     0.040     0.040     0.100     0.300     0.0       0.0       0.0       0.0       0.0
 X1   100.000    10.000   -91.000   562.000   180.000   180.000   180.000     0.0      0.0       0.0
 GR  6730.000  -110.000  6722.598   -91.000  6722.598   145.000  6710.000  237.000  6710.000   337.000
 GR  6702.000   442.000  6702.000   562.000  6705.000   702.000  6715.000  797.000  6730.000   852.000
 EJ     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENOST

*PROF 1

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV= 0.300 CEHV= 0.500
*SECNO 1140.000
3720 CRITICAL DEPTH ASSUMED

1140.00	5.22	6703.72	6703.72	6715.00	6705.73	2.01	0.0	0.0	6698.50
5000.	723.	3848.	429.	94.	313.	56.	0.	0.	6698.50
0.0	7.69	12.28	7.59	0.040	0.040	0.040	0.0	6698.50	63.98
0.012055	0.	0.	0.	0	16	0	0.0	117.63	181.61

*SECNO 972.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

972.00	7.18	6706.04	6706.04	0.0	6709.85	2.81	1.93	0.40	6698.87
5000.	542.	3836.	622.	63.	266.	62.	2.	0.	6698.87
0.00	8.64	14.45	10.05	0.040	0.040	0.040	0.0	6698.87	30.32
0.010925	168.	168.	168.	0	11	0	0.0	70.34	100.66

*SECNO 653.000

3301 HV CHANGED MORE THAN HVINS

653.00	10.06	6709.56	6706.68	0.0	6710.71	1.15	1.37	0.50	6699.50
5000.	725.	3551.	725.	127.	373.	127.	5.	1.	6699.50
0.01	5.71	9.53	5.71	0.040	0.040	0.040	0.0	6699.50	49.82
0.003025	287.	267.	222.	2	5	0	0.0	87.36	137.18

*SECNO 643.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

643.00	7.18	6711.68	6711.68	0.0	6714.50	2.83	0.05	0.84	6704.50
5000.	563.	3873.	563.	64.	265.	64.	5.	1.	6704.50
0.01	8.75	14.53	8.75	0.040	0.040	0.040	0.0	6704.50	57.06
0.011139	10.	10.	10.	0	15	0	0.0	72.88	129.94

← 5' Obstruction

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 633.000

3301 HV CHANGED MORE THAN HVINS

633.00	15.42	6714.92	6706.68	0.0	6715.26	0.34	0.01	0.75	6699.50
5000.	961.	3077.	961.	297.	570.	297.	5.	1.	6699.50
0.01	3.24	5.40	3.24	0.040	0.040	0.040	0.0	6699.50	36.46
0.000550	10.	10.	10.	3	5	0	0.0	114.08	150.54

*SECNO 466.000

466.00	4.19	6715.24	6713.14	0.0	6715.50	0.26	0.22	0.02	6711.05
5000.	54.	4892.	54.	22.	1188.	22.	12.	2.	6711.05
0.03	2.47	4.12	2.47	0.040	0.040	0.040	0.0	6711.05	33.58
0.001818	285.	230.	224.	3	17	0	0.0	304.33	337.92

*SECNO 300.000

7185 MINIMUM SPECIFIC ENERGY

3720 CRITICAL DEPTH ASSUMED

300.00	1.38	6723.98	6723.98	0.0	6724.70	0.72	1.01	0.23	6722.60
5000.	10.	4980.	9.	2.	731.	2.	17.	4.	6722.60
0.04	4.10	6.81	4.08	0.040	0.040	0.040	0.0	6722.60	15.46
0.021926	230.	230.	230.	0	14	0	0.0	536.89	552.35

*SECNO 280.000

280.00	2.10	6724.70	6724.01	0.0	6725.01	0.31	0.19	0.12	6722.60
5000.	15.	4970.	14.	6.	1115.	5.	17.	4.	6722.60
0.04	2.68	4.46	2.67	0.040	0.040	0.040	0.0	6722.60	13.60
0.005338	20.	20.	20.	3	5	0	0.0	540.52	554.12

CCHV= 0.100 CEHV= 0.300

*SECNO 100.000

100.00	23.04	6725.04	6705.05	0.0	6725.04	0.00	0.00	0.03	6722.60
5000.	1.	2739.	2262.	8.	7646.	4628.	45.	8.	6702.00
0.16	0.08	0.36	0.49	0.040	0.040	0.040	0.0	6702.00	-97.26
0.000004	180.	180.	180.	2	11	0	0.0	931.06	833.80

THIS RUN EXECUTED 1/10/85

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MAR  1982
  ERROR CORR -  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
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T1       MIDDLE CREEK DAM
T2       AUXILIARY SPILLWAY - OPTION 3B - RATING CURVE, Q=10000 CFS
T3       HKM ASSOCIATES - 1/85

J1  ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ
     -10.       0.        0.        0. -1.000000      0.0       0.0    10000.  6715.000    0.0
J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE
     2.000     0.0       0.0       0.0       0.0       0.0      -1.000     0.0       0.0       0.0
```

SECNO	OEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 2

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV= 0.300 CEHV= 0.500
*SECNO 1140.000
3720 CRITICAL DEPTH ASSUMED

1140.00	7.73	6706.23	6706.23	6715.00	6709.05	2.81	0.0	0.0	6698.50
10000.	1927.	6930.	1143.	206.	464.	124.	0.	0.	6698.50
0.0	9.34	14.93	9.23	0.040	0.040	0.040	0.0	6698.50	46.66
0.010564	0.	0.	0.	0	13	0	0.0	145.34	192.00

*SECNO 972.000

3301 HV CHANGED MORE THAN HVINS
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

972.00	10.65	6709.52	6709.52	0.0	6713.52	4.00	1.69	0.59	6693.87
10000.	1459.	6952.	1589.	138.	394.	127.	3.	0.	6698.87
0.00	10.55	17.64	12.50	0.040	0.040	0.040	0.0	6698.87	21.85
0.009616	168.	168.	168.	0	11	0	0.0	84.60	106.45

*SECNO 653.000

3301 HV CHANGED MORE THAN HVINS

653.00	14.29	6713.79	6710.21	0.0	6715.50	1.70	1.29	0.69	6699.50
10000.	1834.	6331.	1834.	256.	529.	256.	8.	1.	6699.50
0.01	7.18	11.97	7.18	0.040	0.040	0.040	0.0	6699.50	39.26
0.002992	287.	267.	222.	4	5	0	0.0	108.48	147.74

*SECNO 643.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

643.00	10.71	6715.21	6715.21	0.0	6719.09	3.87	0.05	1.08	6704.50
10000.	1514.	6972.	1514.	144.	395.	144.	8.	1.	6704.50
0.01	10.55	17.59	10.55	0.040	0.040	0.040	0.0	6704.50	48.21
0.009485	10.	10.	10.	0	15	0	0.0	90.57	138.79

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	DLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECND 633.000

3301 HV CHANGED MORE THAN HVINS

633.00	19.96	6719.46	6710.18	0.0	6720.08	0.62	0.02	0.97	6699.50
10000.	2236.	5529.	2236.	498.	738.	498.	8.	1.	6699.50
0.01	4.49	7.49	4.49	0.040	0.040	0.040	0.0	6699.50	25.11
0.000750	10.	10.	10.	4	5	0	0.0	136.79	161.89

*SECND 466.000

466.00	9.09	6720.14	6714.38	0.0	6720.35	0.21	0.15	0.12	6711.05
10000.	228.	9544.	228.	103.	2579.	103.	21.	2.	6711.05
0.03	2.22	3.70	2.22	0.040	0.040	0.040	0.0	6711.05	21.39
0.000523	285.	230.	224.	2	20	0	0.0	328.71	350.11

*SECND 300.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

300.00	2.23	6724.82	6724.82	0.0	6725.92	1.10	0.35	0.45	6722.60
10000.	32.	9937.	30.	6.	1180.	6.	31.	5.	6722.60
0.04	5.06	8.42	5.04	0.040	0.040	0.040	0.0	6722.60	13.28
0.017672	230.	230.	230.	0	14	0	0.0	541.13	554.41

*SECND 280.000

3301 HV CHANGED MORE THAN HVINS

280.00	3.11	6725.71	6724.82	0.0	6726.27	0.56	0.19	0.16	6722.60
10000.	45.	9913.	42.	12.	1647.	12.	32.	5.	6722.60
0.04	3.62	6.02	3.60	0.040	0.040	0.040	0.0	6722.60	11.02
0.005785	20.	20.	20.	4	5	0	0.0	545.53	556.56

CCHV= 0.100 CEHV= 0.300
*SECND 100.000

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLDSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

3301 HV CHANGED MORE THAN HVINS

100.00	24.32	6726.32	6706.26	0.0	6726.32	0.01	0.01	0.06	6722.60
10000.	3.	5627.	4370.	18.	8482.	4979.	63.	8.	6702.00
0.10	0.17	0.66	0.88	0.040	0.040	0.040	0.0	6702.00	-100.54
0.000010	180.	180.	180.	2	11	0	0.0	939.03	838.49

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HEC2 RELEASE DATED NOV 76 UPDATED MAR 1982
ERROR CORR - 01,02,03,04,05
MODIFICATION - 50,51,52,53,54,55
****

THIS RUN EXECUTED 1/10/85

T1 MIDDLE CREEK DAM
T2 AUXILIARY SPILLWAY - OPTION 38 - RATING CURVE, Q=15000 CFS
T3 HKM ASSOCIATES - 1/85

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	-10.	0.	0.	0.	-1.000000	0.0	0.0	15000.	6715.000	0.0

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	3.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 3

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV= 0.300 CEHV= 0.500
*SECNO 1140.000
3720 CRITICAL DEPTH ASSUMED

1140.00	9.67	6708.17	6709.17	6715.00	6711.53	3.36	0.0	0.0	6693.50
15000.	3357.	9653.	1990.	323.	580.	194.	0.	0.	6698.50
0.0	10.41	16.63	10.28	0.040	0.040	0.040	0.0	6698.50	33.30
0.009728	0.	0.	0.	0	10	0	0.0	166.72	200.02

*SECNO 972.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

972.00	13.34	6712.21	6712.21	0.0	6717.07	4.87	1.57	0.75	6698.87
15000.	2567.	9770.	2663.	217.	494.	191.	4.	1.	6698.87
0.00	11.84	19.79	13.31	0.040	0.040	0.040	0.0	6698.87	15.29
0.008964	168.	168.	168.	0	11	0	0.0	95.65	110.94

*SECNO 653.000

3301 HV CHANGED MORE THAN HVINS

653.00	17.57	6717.07	6712.87	0.0	6719.14	2.07	1.23	0.84	6699.50
15000.	3119.	8761.	3119.	386.	650.	386.	11.	1.	6699.50
0.01	8.08	13.48	8.08	0.040	0.040	0.040	0.0	6699.50	31.08
0.002881	287.	267.	222.	4	5	0	0.0	124.84	155.92

*SECNO 643.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

643.00	13.30	6717.80	6717.80	0.0	6722.52	4.72	0.05	1.33	6704.50
15000.	2627.	9746.	2627.	221.	492.	221.	11.	1.	6704.50
0.01	11.88	19.80	11.98	0.040	0.040	0.040	0.0	6704.50	41.75
0.009016	10.	10.	10.	0	15	0	0.0	103.50	145.25

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IOC	ICONT	CORAR	TOPWID	ENDST

*SECNO 633.000

3301 HV CHANGED MORE THAN HVINS

633.00	23.35	6722.85	6712.89	0.0	6723.70	0.85	0.02	1.16	6699.50
15000.	3646.	7707.	3646.	682.	864.	682.	11.	1.	6699.50
0.01	5.35	8.92	5.35	0.040	0.040	0.040	0.0	6699.50	16.62
0.000863	10.	10.	10.	4	5	0	0.0	153.77	170.38

*SECNO 466.000

3301 HV CHANGED MORE THAN HVINS

466.00	12.74	6723.73	6715.41	0.0	6724.02	0.23	0.13	0.19	6711.05
15000.	471.	14059.	471.	202.	3613.	202.	28.	3.	6711.05
0.03	2.33	3.89	2.33	0.040	0.040	0.040	0.0	6711.05	12.33
0.000369	285.	230.	224.	2	21	0	0.0	346.84	359.17

*SECNO 300.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

300.00	2.89	6725.49	6725.49	0.0	6726.94	1.45	0.26	0.61	6722.60
15000.	63.	14878.	59.	11.	1534.	10.	43.	5.	6722.60
0.03	5.83	9.70	5.80	0.040	0.040	0.040	0.0	6722.60	11.57
0.016519	230.	230.	230.	0	17	0	0.0	544.47	556.04

*SECNO 280.000

3301 HV CHANGED MORE THAN HVINS

280.00	3.95	6726.55	6725.47	0.0	6727.33	0.78	0.18	0.20	6722.60
15000.	85.	14834.	80.	20.	2091.	19.	44.	5.	6722.60
0.03	4.26	7.09	4.24	0.040	0.040	0.040	0.0	6722.60	8.87
0.005845	20.	20.	20.	4	6	0	0.0	549.72	558.60

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

CCHV= 0.100 CEHV= 0.300
*SECNO 100.000

3301 HV CHANGED MORE THAN HVINS

100.00	25.40	6727.40	6707.23	0.0	6727.41	0.02	0.01	0.08	6722.60
15000.	8.	8602.	6390.	30.	9190.	5281.	78.	8.	6702.00
0.08	0.28	0.94	1.21	0.040	0.040	0.040	0.0	6702.00	-103.33
0.000019	180.	180.	180.	2	11	0	0.0	945.80	842.47

THIS RUN EXECUTED 1/10/85

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  HEC2 RELEASE DATED NOV 76 UPDATED MAR  1982
  ERROR CORR -  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
**************************************************

T1       MIDDLE CREEK DAM
T2       AUX. SPILLWAY - OPTION 3B - RATING CURVE, Q=20000 CFS
T3       HKM ASSOCIATES - 1/85

J1  ICHECK     INQ       NINV      IDIR       STRT      METRIC    HVINS     Q         WSEL      FQ

    -10.         0.        0.        0. -1.000000       0.0       0.0    20000.  6715.000     0.0

J2  NPROF      IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

      4.000     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
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SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 4

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV= 0.300 CEHV= 0.500
*SECNO 1140.000
3720 CRITICAL DEPTH ASSUMED

1140.00	11.20	6709.70	6709.70	6715.00	6713.58	3.88	0.0	0.0	6698.50
20000.	4907.	12183.	2909.	433.	672.	260.	0.	0.	6698.50
0.0	11.34	18.12	11.20	0.040	0.040	0.040	0.0	6698.50	22.74
0.009494	0.	0.	0.	0	13	0	0.0	183.62	206.36

*SECNO 972.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

972.00	15.60	6714.47	6714.47	0.0	6720.04	5.58	1.51	0.85	6698.87
20000.	3806.	12391.	3803.	296.	577.	255.	5.	1.	6698.87
0.00	12.94	21.46	14.93	0.040	0.040	0.040	0.0	6698.87	9.79
0.008562	163.	168.	168.	0	11	0	0.0	104.91	114.70

*SECNO 653.000

3301 HV CHANGED MORE THAN HVINS

653.00	20.35	6719.85	6715.08	0.0	6722.19	2.34	1.18	0.97	6699.50
20000.	4519.	10962.	4519.	517.	753.	517.	14.	1.	6699.50
0.01	8.73	14.57	8.73	0.040	0.040	0.040	0.0	6699.50	24.15
0.002768	287.	267.	222.	4	5	0	0.0	138.71	162.85

*SECNO 643.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

643.00	15.56	6720.06	6720.06	0.0	6725.36	5.30	0.04	1.48	6704.50
20000.	3867.	12267.	3867.	303.	576.	303.	14.	1.	6704.50
0.01	12.77	21.30	12.77	0.040	0.040	0.040	0.0	6704.50	36.09
0.008462	10.	10.	10.	0	15	0	0.0	114.81	150.91

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 633.000

3301 HV CHANGED MORE THAN HVINS

633.00	26.10	6725.60	6715.11	0.0	6726.66	1.06	0.02	1.27	6699.50
20000.	5140.	9721.	5140.	852.	966.	852.	14.	1.	6699.50
0.01	6.03	10.07	6.03	0.040	0.040	0.040	0.0	6699.50	9.74
0.000948	10.	10.	10.	4	5	0	0.0	167.51	177.26

*SECNO 466.000

3301 HV CHANGED MORE THAN HVINS

466.00	15.71	6726.76	6716.35	0.0	6727.02	0.25	0.12	0.24	6711.05
20000.	763.	18475.	763.	307.	4453.	307.	35.	3.	6711.05
0.03	2.49	4.15	2.49	0.040	0.040	0.040	0.0	6711.05	4.96
0.000317	285.	230.	224.	0	17	0	0.0	361.53	366.54

*SECNO 300.000

3301 HV CHANGED MORE THAN HVINS

300.00	3.74	6726.33	6725.10	0.0	6727.38	1.54	0.22	0.64	6722.60
20000.	108.	19791.	101.	18.	1980.	17.	54.	5.	6722.60
0.03	6.01	10.00	5.98	0.040	0.040	0.040	0.0	6722.60	9.41
0.012498	230.	230.	230.	3	17	0	0.0	548.67	558.08

*SECNO 280.000

3301 HV CHANGED MORE THAN HVINS

280.00	4.59	6727.19	6726.14	0.0	6728.20	1.01	0.17	0.15	6722.60
20000.	132.	19743.	125.	27.	2436.	26.	55.	5.	6722.60
0.03	4.87	8.11	4.95	0.040	0.040	0.040	0.0	6722.60	7.20
0.006229	20.	20.	20.	5	12	0	0.0	552.97	560.18

CCHV= 0.100 CEHV= 0.300
*SECNO 100.000

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

3301 HV CHANGED MORE THAN HVINS

100.00	26.29	6728.29	6708.10	0.0	6728.32	0.03	0.02	0.10	6722.60
20000.	16.	11622.	8362.	42.	9770.	5532.	92.	9.	6702.00
0.07	0.38	1.19	1.51	0.040	0.040	0.040	0.0	6702.00	-105.61
0.000028	180.	180.	180.	2	11	0	0.0	951.33	845.73

THIS RUN EXECUTED 1/10/85

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MAR  1982
  ERROR CORR -  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
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T1       MIDDLE CREEK DAM
T2       AUX. SPILLWAY - OPTION 3B - RATING CURVE, Q=25000 CFS
T3       HKM ASSOCIATES - 1/85

J1  ICHECK     INQ       NINV      IDIR       STRT      METRIC    HVINS     Q         WSEL      FQ

     -10.        0.        0.        0. -1.000000       0.0       0.0   25000.  6715.000     0.0

J2  NPROF      IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

      5.000     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	DLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 5

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV= 0.300 CEHV= 0.500

*SECND 1140.000

3720 CRITICAL DEPTH ASSUMED

1140.00	12.68	6711.18	6711.18	6715.00	6715.36	4.17	0.0	0.0	6698.50
25000.	6506.	14478.	3916.	555.	761.	333.	0.	0.	6698.50
0.0	11.90	19.02	11.76	0.040	0.040	0.040	0.0	6698.50	12.53
0.008965	0.	0.	0.	0	15	0	0.0	199.96	212.48

*SECND 972.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY

3720 CRITICAL DEPTH ASSUMED

972.00	17.65	6716.52	6716.52	0.0	6722.63	6.12	1.43	0.97	6698.87
25000.	5157.	14842.	5001.	379.	653.	319.	6.	1.	6698.87
0.00	13.59	22.73	15.66	0.040	0.040	0.040	0.0	6698.87	4.81
0.008145	168.	168.	168.	0	11	0	0.0	113.31	118.11

*SECND 653.000

3301 HV CHANGED MORE THAN HVINS

653.00	22.76	6722.25	6716.96	0.0	6724.82	2.57	1.13	1.06	6699.50
25000.	5996.	13008.	5996.	647.	842.	647.	16.	1.	6699.50
0.01	9.26	15.45	9.26	0.040	0.040	0.040	0.0	6699.50	18.10
0.002681	287.	267.	222.	5	5	0	0.0	150.79	169.90

*SECND 643.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY

3720 CRITICAL DEPTH ASSUMED

643.00	17.43	6721.93	6721.93	0.0	6727.82	5.89	0.04	1.66	6704.50
25000.	5173.	14654.	5173.	380.	645.	380.	17.	1.	6704.50
0.01	13.62	22.72	13.62	0.040	0.040	0.040	0.0	6704.50	31.43
0.008277	10.	10.	10.	0	15	0	0.0	124.15	155.57

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 633.000

3301 HV CHANGED MORE THAN HVINS

633.00	28.50	6728.00	6717.02	0.0	6729.24	1.23	0.02	1.40	6699.50
25000.	6699.	11602.	6699.	1016.	1055.	1016.	17.	1.	6699.50
0.01	6.60	11.00	6.60	0.040	0.040	0.040	0.0	6699.50	3.74
0.001007	10.	10.	10.	4	5	0	0.0	179.51	183.26

*SECNO 466.000
3280 CROSS SECTION 466.00 EXTENDED 0.61 FEET

3301 HV CHANGED MORE THAN HVINS

466.00	18.31	6729.35	6717.20	0.0	6729.64	0.28	0.12	0.29	6711.05
25000.	1109.	22782.	1109.	416.	5191.	416.	42.	3.	6711.05
0.02	2.66	4.39	2.66	0.040	0.040	0.040	0.0	6711.05	0.0
0.000289	285.	230.	224.	2	18	0	0.0	371.50	371.50

*SECNO 300.000

300.00	6.68	6729.28	6726.64	0.0	6730.01	0.74	0.15	0.23	6722.60
25000.	239.	24536.	225.	57.	3543.	54.	68.	5.	6722.60
0.03	4.16	6.92	4.14	0.040	0.040	0.040	0.0	6722.60	1.84
0.002759	230.	230.	230.	2	17	0	0.0	563.42	565.26

*SECNO 280.000

280.00	6.75	6729.34	6726.66	0.0	6730.07	0.72	0.05	0.00	6722.60
25000.	241.	24532.	227.	58.	3575.	55.	69.	6.	6722.60
0.03	4.12	6.86	4.10	0.040	0.040	0.040	0.0	6722.60	1.68
0.002675	20.	20.	20.	2	15	0	0.0	563.72	565.41

CCHV= 0.100 CEHV= 0.300
*SECNO 100.000
3280 CROSS SECTION 100.00 EXTENDED 0.12 FEET

3301 HV CHANGED MORE THAN HVINS

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENOST
100.00	28.12	6730.12	6708.89	0.0	6730.15	0.03	0.02	0.07	6722.60
25000.	35.	14854.	10111.	73.	10965.	6057.	112.	9.	6702.00
0.07	0.48	1.35	1.67	0.040	0.040	0.040	0.0	6702.00	-110.00
0.000031	180.	180.	180.	2	5	0	0.0	962.00	852.00

THIS RUN EXECUTED 1/10/85

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MAR  1982
  ERROR CORR -  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
**************************************************

T1       MIDDLE CREEK DAM
T2       AUXILIARY SPILLWAY - OPTION 3B - RATING CURVE, Q = 29030 CFS
T3       HKM ASSOCIATES - 1/85

J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ

     -10.        0.        0.        0. -1.000000       0.0       0.0   29030.  6715.000     0.0

J2  NPROF      IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

     15.000     0.0       0.0       0.0       0.0       0.0      -1.000     0.0       0.0       0.0
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SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IOC	ICONT	CORAR	TOPWIO	ENDST

#PROF 6

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV= 0.300 CEHV= 0.500
#SECNO 1140.000
3720 CRITICAL DEPTH ASSUMED

1140.00	13.50	6712.00	6712.00	6715.00	6716.65	4.64	0.0	0.0	6698.50
29030.	7950.	16367.	4713.	629.	810.	377.	0.	0.	6698.50
0.0	12.64	20.20	12.49	0.040	0.040	0.040	0.0	6698.50	6.87
0.009192	0.	0.	0.	0	11	0	0.0	209.01	215.88

#SECNO 972.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

972.00	19.19	6718.05	6718.05	0.0	6724.51	6.46	1.42	0.91	6693.87
29030.	6315.	16715.	6000.	448.	710.	373.	6.	1.	6698.87
0.00	14.08	23.54	16.10	0.040	0.040	0.040	0.0	6698.87	1.06
0.007818	168.	168.	168.	0	11	0	0.0	119.62	120.68

#SECNO 653.000

3301 HV CHANGED MORE THAN HVINS

653.00	24.50	6724.00	6718.33	0.0	6726.73	2.73	1.10	1.12	6699.50
29030.	7230.	14569.	7230.	750.	907.	750.	18.	1.	6699.50
0.01	9.64	16.07	9.64	0.040	0.040	0.040	0.0	6699.50	13.75
0.002629	287.	267.	222.	5	5	0	0.0	159.50	173.25

#SECNO 643.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

643.00	18.88	6723.38	6723.38	0.0	6729.60	6.22	0.04	1.74	6704.50	← 5' obstruction
29030.	6291.	16447.	6291.	446.	699.	446.	19.	1.	6704.50	
0.01	14.12	23.55	14.12	0.040	0.040	0.040	0.0	6704.50	27.80	
0.007990	10.	10.	10.	0	15	0	0.0	131.39	159.20	

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 633.000
3280 CROSS SECTION 633.00 EXTENDED 0.20 FEET

3301 HV CHANGED MORE THAN HVINS

633.00	30.20	6729.70	6718.40	0.0	6731.07	1.37	0.02	1.45	6699.50
29030.	7997.	13036.	7997.	1140.	1118.	1140.	19.	2.	6699.50
0.01	7.01	11.67	7.01	0.040	0.040	0.040	0.0	6699.50	0.0
0.001048	10.	10.	10.	4	5	0	0.0	187.00	187.00

*SECNO 466.000
3280 CROSS SECTION 466.00 EXTENDED 2.45 FEET

3301 HV CHANGED MORE THAN HVINS

466.00	20.15	6731.20	6717.90	0.0	6731.51	0.31	0.12	0.32	6711.05
29030.	1425.	26179.	1425.	497.	5714.	497.	47.	3.	6711.05
0.02	2.97	4.58	2.87	0.040	0.040	0.040	0.0	6711.05	0.0
0.000277	285.	230.	224.	2	17	0	0.0	371.50	371.50

*SECNO 300.000
3280 CROSS SECTION 300.00 EXTENDED 1.19 FEET

300.00	8.59	6731.19	6727.11	0.0	6731.78	0.59	0.13	0.14	6722.60
29030.	365.	28322.	343.	93.	4552.	88.	77.	6.	6722.60
0.03	3.93	6.22	3.90	0.040	0.040	0.040	0.0	6722.60	0.0
0.001595	230.	230.	230.	2	17	0	0.0	567.00	567.00

*SECNO 280.000
3280 CROSS SECTION 280.00 EXTENDED 1.22 FEET

280.00	8.62	6731.22	6727.08	0.0	6731.81	0.59	0.03	0.00	6722.60
29030.	366.	28319.	345.	94.	4571.	89.	79.	6.	6722.60
0.03	3.91	6.20	3.89	0.040	0.040	0.040	0.0	6722.60	0.0
0.001573	20.	20.	20.	2	11	0	0.0	567.00	567.00

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

CCHV= 0.100 CEHV= 0.300
*SECNO 100.000
3280 CROSS SECTION 100.00 EXTENDED 1.84 FEET

3301 HV CHANGED MORE THAN HVINS

100.00	29.84	6731.84	6709.45	0.0	6731.88	0.04	0.02	0.05	6722.60
29030.	62.	17522.	11447.	105.	12090.	6556.	128.	9.	6702.00
0.07	0.58	1.45	1.75	0.040	0.040	0.040	0.0	6702.00	-110.00
0.000031	180.	180.	180.	2	8	0	0.0	962.00	852.00

THIS RUN EXECUTED 1/10/85

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**************************************************
  HEC2 RELEASE DATED NOV 75 UPDATED MAR  1982
  ERROR CORR -  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

HKM ASSOCIATES - 1/85

SUMMARY PRINTOUT TABLE 150

	SECNO	XLCH	ELTRO	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10K*S	VCH	AREA	.01K
*	1140.000	0.0	0.0	0.0	6698.50	5000.00	6703.72	6703.72	6705.73	120.55	12.28	463.96	455.39
*	1140.000	0.0	0.0	0.0	6698.50	10000.00	6706.23	6706.23	6709.04	105.64	14.93	794.11	972.96
*	1140.000	0.0	0.0	0.0	6693.50	15000.00	6708.17	6708.17	6711.53	97.28	16.63	1096.42	1520.83
*	1140.000	0.0	0.0	0.0	6698.50	20000.00	6709.70	6709.70	6713.58	94.94	18.12	1364.66	2052.61
*	1140.000	0.0	0.0	0.0	6698.50	25000.00	6711.18	6711.18	6715.36	88.65	19.02	1648.97	2655.29
*	1140.000	0.0	0.0	0.0	6698.50	29030.00	6712.00	6712.00	6716.65	91.92	20.20	1816.62	3027.83
*	972.000	168.00	0.0	0.0	6698.87	5000.00	6706.04	6706.04	6708.85	109.25	14.45	390.16	478.37
*	972.000	168.00	0.0	0.0	6698.87	10000.00	6709.52	6709.52	6713.52	96.16	17.54	659.51	1019.76
*	972.000	168.00	0.0	0.0	6698.87	15000.00	6712.21	6712.21	6717.07	89.64	19.79	902.04	1594.31
*	972.000	168.00	0.0	0.0	6698.87	20000.00	6714.47	6714.47	6720.04	85.62	21.46	1128.46	2151.44
*	972.000	168.00	0.0	0.0	6698.87	25000.00	6716.52	6716.52	6722.63	81.45	22.73	1351.79	2770.03
*	972.000	168.00	0.0	0.0	6698.87	29030.00	6718.05	6718.05	6724.51	78.18	23.54	1531.04	3293.26
	653.000	267.00	0.0	0.0	6699.50	5000.00	6709.56	6706.68	6710.71	30.25	9.53	626.25	909.14
	653.000	267.00	0.0	0.0	6699.50	10000.00	6713.79	6710.21	6715.50	29.92	11.97	1040.04	1828.29
	653.000	267.00	0.0	0.0	6699.50	15000.00	6717.07	6712.87	6719.14	28.81	13.48	1421.97	2734.51
	653.000	267.00	0.0	0.0	6699.50	20000.00	6719.85	6715.08	6722.19	27.68	14.57	1787.39	3801.64
	653.000	267.00	0.0	0.0	6699.50	25000.00	6722.25	6716.96	6724.82	26.81	15.45	2136.38	4828.71
	653.000	267.00	0.0	0.0	6699.50	29030.00	6724.00	6718.33	6726.73	26.29	16.07	2407.33	5661.43
*	643.000	10.00	0.0	0.0	6704.50	5000.00	6711.68	6711.68	6714.50	111.39	14.59	394.30	473.75
*	643.000	10.00	0.0	0.0	6704.50	10000.00	6715.21	6715.21	6719.09	94.85	17.59	683.57	1026.79
*	643.000	10.00	0.0	0.0	6704.50	15000.00	6717.80	6717.80	6722.52	90.16	19.30	934.54	1579.73
*	643.000	10.00	0.0	0.0	6704.50	20000.00	6720.06	6720.06	6725.36	84.62	21.30	1181.29	2174.20
*	643.000	10.00	0.0	0.0	6704.50	25000.00	6721.93	6721.93	6727.82	82.77	22.72	1404.38	2747.97
*	643.000	10.00	0.0	0.0	6704.50	29030.00	6723.38	6723.38	6729.60	79.90	23.55	1589.74	3247.75
	633.000	10.00	0.0	0.0	6699.50	5000.00	6714.91	6706.68	6715.26	5.50	5.40	1164.70	2132.82
	633.000	10.00	0.0	0.0	6699.50	10000.00	6719.45	6710.18	6720.08	7.50	7.49	1734.37	3651.03
	633.000	10.00	0.0	0.0	6699.50	15000.00	6722.85	6712.89	6723.70	8.63	8.32	2227.64	5104.69
	633.000	10.00	0.0	0.0	6699.50	20000.00	6725.60	6715.11	6726.66	9.48	10.07	2663.20	6436.43
	633.000	10.00	0.0	0.0	6699.50	25000.00	6728.00	6717.02	6729.24	10.07	11.00	3085.14	7878.33
	633.000	10.00	0.0	0.0	6699.50	29030.00	6729.70	6718.40	6731.07	10.48	11.67	3397.94	8967.02

	SECNO	XLCH	ELTRO	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10K*S	VCH	AREA	.01K
	466.000	230.00	0.0	0.0	6711.05	5000.00	6715.23	6713.14	6715.50	18.18	4.12	1231.70	1172.52
	466.000	230.00	0.0	0.0	6711.05	10000.00	6720.14	6714.38	6720.35	5.23	3.70	2784.31	4374.05
	466.000	230.00	0.0	0.0	6711.05	15000.00	6723.79	6715.41	6724.02	3.69	3.89	4016.35	7813.16
	466.000	230.00	0.0	0.0	6711.05	20000.00	6726.76	6716.35	6727.02	3.17	4.15	5066.28	11232.78
	466.000	230.00	0.0	0.0	6711.05	25000.00	6729.35	6717.20	6729.64	2.89	4.39	6023.80	14704.46
	466.000	230.00	0.0	0.0	6711.05	29030.00	6731.20	6717.80	6731.51	2.77	4.58	6708.52	17434.18
*	300.000	230.00	0.0	0.0	6722.60	5000.00	6723.98	6723.98	6724.70	219.26	6.81	735.59	337.67
*	300.000	230.00	0.0	0.0	6722.60	10000.00	6724.82	6724.82	6725.92	176.72	8.42	1192.47	752.25
*	300.000	230.00	0.0	0.0	6722.60	15000.00	6725.49	6725.49	6726.94	165.19	9.70	1555.07	1157.06
	300.000	230.00	0.0	0.0	6722.60	20000.00	6726.33	6726.10	6727.88	124.98	10.00	2014.37	1739.02
	300.000	230.00	0.0	0.0	6722.60	25000.00	6729.27	6726.64	6730.01	27.59	6.92	3654.99	4759.95
	300.000	230.00	0.0	0.0	6722.60	29030.00	6731.18	6727.11	6731.78	15.95	6.22	4732.71	7269.46
	280.000	20.00	0.0	0.0	6722.60	5000.00	6724.70	6724.01	6725.01	53.38	4.46	1126.28	684.36
	280.000	20.00	0.0	0.0	6722.60	10000.00	6725.70	6724.82	6726.27	57.85	6.02	1671.38	1314.75
	280.000	20.00	0.0	0.0	6722.60	15000.00	6726.55	6725.47	6727.33	59.45	7.09	2130.38	1961.99
	280.000	20.00	0.0	0.0	6722.60	20000.00	6727.19	6726.14	6728.20	62.29	8.11	2489.63	2534.05
	280.000	20.00	0.0	0.0	6722.60	25000.00	6729.34	6726.66	6730.07	26.75	6.36	3689.59	4833.98
	280.000	20.00	0.0	0.0	6722.60	29030.00	6731.22	6727.08	6731.81	15.73	6.20	4752.71	7320.01
	100.000	180.00	0.0	0.0	6702.00	5000.00	6725.04	6705.05	6725.04	0.04	0.36	12282.34	26722.68
	100.000	180.00	0.0	0.0	6702.00	10000.00	6726.31	6706.26	6726.32	0.10	0.66	13473.16	30906.81
	100.000	180.00	0.0	0.0	6702.00	15000.00	6727.39	6707.23	6727.41	0.19	0.94	14500.96	34666.69
	100.000	180.00	0.0	0.0	6702.00	20000.00	6728.29	6708.10	6728.32	0.28	1.19	15343.67	37834.87
	100.000	180.00	0.0	0.0	6702.00	25000.00	6730.12	6708.89	6730.15	0.31	1.35	17093.33	44905.40
	100.000	180.00	0.0	0.0	6702.00	29030.00	6731.84	6709.45	6731.88	0.31	1.45	18751.11	52018.89

HKM ASSOCIATES - 1/85

SUMMARY PRINTOUT TABLE 150

	SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
*	1140.000	5000.00	6703.72	0.0	0.0	-11.28	117.63	0.0
*	1140.000	10000.00	6706.23	2.51	0.0	-8.77	145.34	0.0
*	1140.000	15000.00	6708.17	1.94	0.0	-6.83	166.72	0.0
*	1140.000	20000.00	6709.70	1.53	0.0	-5.30	183.62	0.0
*	1140.000	25000.00	6711.18	1.48	0.0	-3.82	199.96	0.0
*	1140.000	29030.00	6712.00	0.82	0.0	-3.00	209.01	0.0
*	972.000	5000.00	6706.04	0.0	2.32	0.0	70.34	168.00
*	972.000	10000.00	6709.52	3.48	3.29	0.0	84.60	168.00
*	972.000	15000.00	6712.21	2.69	4.04	0.0	95.65	168.00
*	972.000	20000.00	6714.47	2.26	4.77	0.0	104.91	168.00
*	972.000	25000.00	6716.52	2.05	5.33	0.0	113.31	168.00
*	972.000	29030.00	6718.05	1.54	6.05	0.0	119.52	168.00
	653.000	5000.00	6709.56	0.0	3.52	0.0	87.36	267.00
	653.000	10000.00	6713.79	4.23	4.27	0.0	108.48	267.00
	653.000	15000.00	6717.07	3.28	4.86	0.0	124.84	267.00
	653.000	20000.00	6719.85	2.78	5.38	0.0	138.71	267.00
	653.000	25000.00	6722.25	2.41	5.74	0.0	150.79	267.00
	653.000	29030.00	6724.00	1.74	5.94	0.0	159.50	267.00
*	643.000	5000.00	6711.68	0.0	2.11	0.0	72.88	10.00
*	643.000	10000.00	6715.21	3.54	1.42	0.0	90.57	10.00
*	643.000	15000.00	6717.80	2.59	0.73	0.0	103.50	10.00
*	643.000	20000.00	6720.06	2.26	0.21	0.0	114.81	10.00
*	643.000	25000.00	6721.93	1.87	-0.32	0.0	124.15	10.00
*	643.000	29030.00	6723.38	1.45	-0.62	0.0	131.39	10.00
	633.000	5000.00	6714.91	0.0	3.24	0.0	114.08	10.00
	633.000	10000.00	6719.45	4.54	4.24	0.0	136.79	10.00
	633.000	15000.00	6722.85	3.40	5.05	0.0	153.77	10.00
	633.000	20000.00	6725.60	2.75	5.54	0.0	167.51	10.00
	633.000	25000.00	6728.00	2.41	6.07	0.0	179.51	10.00
	633.000	29030.00	6729.70	1.70	6.33	0.0	187.00	10.00
	466.000	5000.00	6715.23	0.0	0.32	0.0	304.33	230.00
	466.000	10000.00	6720.14	4.91	0.69	0.0	328.71	230.00
	466.000	15000.00	6723.79	3.65	0.94	0.0	346.84	230.00
	466.000	20000.00	6726.76	2.97	1.16	0.0	361.58	230.00
	466.000	25000.00	6729.35	2.59	1.35	0.0	371.50	230.00
	466.000	29030.00	6731.20	1.85	1.50	0.0	371.50	230.00

	SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
*	300.000	5000.00	6723.98	0.0	8.74	0.0	536.89	230.00
*	300.000	10000.00	6724.92	0.85	4.68	0.0	541.13	230.00
*	300.000	15000.00	6725.49	0.67	1.70	0.0	544.47	230.00
	300.000	20000.00	6726.33	0.84	-0.42	0.0	548.67	230.00
	300.000	25000.00	6729.27	2.94	-0.08	0.0	563.42	230.00
	300.000	29030.00	6731.18	1.91	-0.01	0.0	567.00	230.00
	280.000	5000.00	6724.70	0.0	0.72	0.0	540.52	20.00
	280.000	10000.00	6725.70	1.00	0.38	0.0	545.53	20.00
	280.000	15000.00	6726.55	0.85	1.06	0.0	549.72	20.00
	280.000	20000.00	6727.19	0.64	0.86	0.0	552.97	20.00
	280.000	25000.00	6729.34	2.16	0.07	0.0	563.72	20.00
	280.000	29030.00	6731.22	1.88	0.04	0.0	567.00	20.00
	100.000	5000.00	6725.04	0.0	0.34	0.0	931.06	180.00
	100.000	10000.00	6726.31	1.28	0.61	0.0	939.03	180.00
	100.000	15000.00	6727.39	1.08	0.85	0.0	945.80	180.00
	100.000	20000.00	6728.29	0.89	1.10	0.0	951.33	180.00
	100.000	25000.00	6730.12	1.83	0.77	0.0	962.00	180.00
	100.000	29030.00	6731.84	1.72	0.62	0.0	962.00	180.00

SUMMARY OF ERRORS AND SPECIAL NOTES

```
CAUTION  SECNO= 1140.000  PROFILE= 1  CRITICAL DEPTH ASSUMED
CAUTION  SECNO= 1140.000  PROFILE= 2  CRITICAL DEPTH ASSUMED
CAUTION  SECNO= 1140.000  PROFILE= 3  CRITICAL DEPTH ASSUMED
CAUTION  SECNO= 1140.000  PROFILE= 4  CRITICAL DEPTH ASSUMED
CAUTION  SECNO= 1140.000  PROFILE= 5  CRITICAL DEPTH ASSUMED
CAUTION  SECNO= 1140.000  PROFILE= 6  CRITICAL DEPTH ASSUMED

CAUTION  SECNO=  972.000  PROFILE= 1  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  972.000  PROFILE= 1  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  972.000  PROFILE= 2  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  972.000  PROFILE= 2  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  972.000  PROFILE= 3  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  972.000  PROFILE= 3  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  972.000  PROFILE= 4  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  972.000  PROFILE= 4  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  972.000  PROFILE= 5  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  972.000  PROFILE= 5  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  972.000  PROFILE= 6  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  972.000  PROFILE= 6  MINIMUM SPECIFIC ENERGY

CAUTION  SECNO=  643.000  PROFILE= 1  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  643.000  PROFILE= 1  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  643.000  PROFILE= 2  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  643.000  PROFILE= 2  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  643.000  PROFILE= 3  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  643.000  PROFILE= 3  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  643.000  PROFILE= 4  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  643.000  PROFILE= 4  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  643.000  PROFILE= 5  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  643.000  PROFILE= 5  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  643.000  PROFILE= 6  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  643.000  PROFILE= 6  MINIMUM SPECIFIC ENERGY

CAUTION  SECNO=  300.000  PROFILE= 1  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  300.000  PROFILE= 1  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  300.000  PROFILE= 2  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  300.000  PROFILE= 2  MINIMUM SPECIFIC ENERGY
CAUTION  SECNO=  300.000  PROFILE= 3  CRITICAL DEPTH ASSUMED
CAUTION  SECNO=  300.000  PROFILE= 3  MINIMUM SPECIFIC ENERGY
```

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*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             FEBRUARY 1981             *
*          REVISED 04 NOV 81            *
*                                       *
*  RUN DATE (MM/DD/YY)  3/10/96         *
*                                       *
*****************************************
```

```
*****************************************
*                                       *
*    U.S. ARMY CORPS OF ENGINEERS       *
*  THE HYDROLOGIC ENGINEERING CENTER    *
*         609 SECOND STREET             *
*       DAVIS, CALIFORNIA 95616         *
*  (916) 440-3285 OR (FTS) 448-3285     *
*                                       *
*****************************************
```

```
X      X  XXXXXXX   XXXXX            X
X      X  X        X     X          XX
X      X  X        X                 X
XXXXXXX  XXXX     X         XXXXX    X
X      X  X        X                 X
X      X  X        X     X           X
X      X  XXXXXXX   XXXXX            XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. SEE SEPTEMBER 1981 INPUT
DESCRIPTION FOR NEW DEFINITIONS.

```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10
    1     ID          MIDDLE CREEK DAM
    2     ID          SPILLWAY DESIGN ROUTING - PROPOSED PROJECT - PMF
    3     ID          HKM ASSOCIATES 9/84
    4     IT      12  1JUN83     900     250
    5     IN      30  1JUN83     900
    6     ID       0
    7     VS      IN      IN     OUT     OUT
    8     VV    2.11    7.11    2.11    7.11

    9     KK      IN  PMF INFLOW TO MIDDLE CREEK RESERVOIR
   10     BA      27
   11     QI     260     296     427     643     891    1113    1329    1522    1699    1860
   12     QI    2006    2139    2253    2367    2465    2553    2634    2706    2772    2831
   13     QI    2885    2934    2978    3018    3054    3086    3116    3143    3167    3234
   14     QI    3415    3745    4210    4751    5286    5770    6207    6603    6962    7286
   15     QI    7579    7854    8162    8562    9080    9489    9904   10280   12520   12933
   16     QI   13330   13710   14062   14562   16142   20501   26939   31575   32413   31299
   17     QI   30040   28305   27350   26269   25103   24030   23059   22180   21385   20567
   18     QI   20016   19427   18895   18368   17761   17031   16205   15352   14542   13809
   19     QI   13145   12544   12000   11503   11063   10615   10089    9492    8907    8377
   20     QI    8103    8103    8103    8103    8103    8103    8103    8103    8103    8103

   21     KK     OUT  MIDDLE CREEK DAM COMBINED SPILLWAYS
   22     RS       1    STOR   10310
   23     SV     126     211     675    2211    3282    4570    6044    7976   10310   10820
   24     SE    6537    6640    6650    6670    6680    6690    6700  6710.8  6721.0    6730
   25     SQ       0     483    1015    2180    4630    7990   12970   21730   32750
   26     SE  6721.0  6722.0  6722.6  6723.1  6724.2 6725.24 6726.41 6728.17    6730
   27     ZZ
```

Spillway Design Flood

P.M.F

HEC-1 Output 2/10/84
Middle Cr. Res. Combined
Spillway Routing of 1/2 PMF
Option 2E, road up spillway,
HEEK Structures

Reid THICK

Input = THEC1SPL

```
**************************************
*                                    *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)*
*             FEBRUARY 1981          *
*           REVISED 04 NOV 81        *
*                                    *
*  RUN DATE (MM/DD/YY)  3/10/84      *
*                                    *
**************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*  THE HYDROLOGIC ENGINEERING CENTER   *
*         609 SECOND STREET            *
*       DAVIS, CALIFORNIA 95616        *
*  (916) 440-3285 OR (FTS) 448-3285    *
*                                      *
****************************************
```

MIDDLE CREEK DAM
SPILLWAY DESIGN ROUTING - PROPOSED PROJECT - PMF
HKM ASSOCIATES 6/84

6 IO OUTPUT CONTROL VARIABLES

IPRNT	0	PRINT CONTROL
IPLOT	0	PLOT CONTROL
QSCAL	0.	HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA

NMIN	12	MINUTES IN COMPUTATION INTERVAL
IDATE	1JUN33	STARTING DATE
ITIME	0900	STARTING TIME
NQ	250	NUMBER OF HYDROGRAPH ORDINATES
NDDATE	3JUN33	ENDING DATE
NDTIME	1048	ENDING TIME

COMPUTATION INTERVAL 0.20 HOURS
TOTAL TIME BASE 49.80 HOURS

ENGLISH UNITS

DRAINAGE AREA	SQUARE MILES
PRECIPITATION DEPTH	INCHES
LENGTH, ELEVATION	FEET
FLOW	CUBIC FEET PER SECOND
STORAGE VOLUME	ACRE-FEET
SURFACE AREA	ACRES
TEMPERATURE	DEGREES FAHRENHEIT

USER-DEFINED OUTPUT SPECIFICATIONS

TABLE 1

VS	STATION	IN	IN	OUT	OUT						
VV	VARIABLE CODE	2.11	7.11	2.11	7.11	0.0	0.0	0.0	0.0	0.0	0.0

*** ***

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**************
*            *
*     IN     *
*            *
**************
```

9 KK PMF INFLOW TO MIDDLE CREEK RESERVOIR

JXTIME 900 STARTING TIME

SUBBASIN RUNOFF DATA

10 BA SUBBASIN CHARACTERISTICS
TAREA 27.00 SUBBASIN AREA

***

HYDROGRAPH AT STATION IN

DA	MON	HRMN	ORD	FLOW	DA	MON	HRMN	ORD	FLOW	DA	MON	HRMN	ORD	FLOW	DA	MON	HRMN	ORD	FLOW
1	JUN	0900	1	260.	1	JUN	2136	64	3092.	2	JUN	1012	127	13482.	2	JUN	2248	190	16535.
1	JUN	0912	2	274.	1	JUN	2148	65	3104.	2	JUN	1024	128	13634.	2	JUN	2300	191	16205.
1	JUN	0924	3	289.	1	JUN	2200	66	3116.	2	JUN	1036	129	13790.	2	JUN	2312	192	15964.
1	JUN	0936	4	322.	1	JUN	2212	67	3127.	2	JUN	1048	130	13921.	2	JUN	2324	193	15523.
1	JUN	0948	5	375.	1	JUN	2224	68	3138.	2	JUN	1100	131	14062.	2	JUN	2336	194	15190.
1	JUN	1000	6	427.	1	JUN	2236	69	3148.	2	JUN	1112	132	14262.	2	JUN	2348	195	14966.
1	JUN	1012	7	515.	1	JUN	2248	70	3157.	2	JUN	1124	133	14462.	3	JUN	0000	196	14542.
1	JUN	1024	8	604.	1	JUN	2300	71	3167.	2	JUN	1136	134	14878.	3	JUN	0012	197	14249.
1	JUN	1036	9	697.	1	JUN	2312	72	3194.	2	JUN	1148	135	15510.	3	JUN	0024	198	13956.
1	JUN	1048	10	794.	1	JUN	2324	73	3221.	2	JUN	1200	136	16142.	3	JUN	0036	199	13676.
1	JUN	1100	11	891.	1	JUN	2336	74	3270.	2	JUN	1212	137	17886.	3	JUN	0048	200	13411.
1	JUN	1112	12	992.	1	JUN	2348	75	3343.	2	JUN	1224	138	19629.	3	JUN	0100	201	13145.
1	JUN	1124	13	1073.	2	JUN	0000	76	3415.	2	JUN	1236	139	21789.	3	JUN	0112	202	12905.
1	JUN	1136	14	1150.	2	JUN	0012	77	3547.	2	JUN	1248	140	24364.	3	JUN	0124	203	12664.
1	JUN	1148	15	1245.	2	JUN	0024	78	3679.	2	JUN	1300	141	26939.	3	JUN	0136	204	12435.
1	JUN	1200	16	1329.	2	JUN	0036	79	3838.	2	JUN	1312	142	28793.	3	JUN	0148	205	12218.
1	JUN	1212	17	1406.	2	JUN	0048	80	4024.	2	JUN	1324	143	30648.	3	JUN	0200	206	12000.
1	JUN	1224	18	1483.	2	JUN	0100	81	4210.	2	JUN	1336	144	31743.	3	JUN	0212	207	11801.
1	JUN	1236	19	1557.	2	JUN	0112	82	4426.	2	JUN	1348	145	32078.	3	JUN	0224	208	11602.
1	JUN	1248	20	1628.	2	JUN	0124	83	4643.	2	JUN	1400	146	32413.	3	JUN	0236	209	11415.
1	JUN	1300	21	1699.	2	JUN	0136	84	4858.	2	JUN	1412	147	31967.	3	JUN	0248	210	11239.
1	JUN	1312	22	1763.	2	JUN	0148	85	5072.	2	JUN	1424	148	31522.	3	JUN	0300	211	11063.
1	JUN	1324	23	1829.	2	JUN	0200	86	5286.	2	JUN	1436	149	31047.	3	JUN	0312	212	10884.
1	JUN	1336	24	1839.	2	JUN	0212	87	5480.	2	JUN	1448	150	30544.	3	JUN	0324	213	10705.
1	JUN	1348	25	1948.	2	JUN	0224	88	5673.	2	JUN	1500	151	30040.	3	JUN	0336	214	10510.
1	JUN	1400	26	2026.	2	JUN	0236	89	5857.	2	JUN	1512	152	29546.	3	JUN	0348	215	10299.
1	JUN	1412	27	2059.	2	JUN	0248	90	6032.	2	JUN	1524	153	29052.	3	JUN	0400	216	10089.
1	JUN	1424	28	2112.	2	JUN	0300	91	6207.	2	JUN	1536	154	28554.	3	JUN	0412	217	9850.
1	JUN	1436	29	2162.	2	JUN	0312	92	6365.	2	JUN	1548	155	28052.	3	JUN	0424	218	9611.
1	JUN	1448	30	2210.	2	JUN	0324	93	6524.	2	JUN	1600	156	27550.	3	JUN	0436	219	9375.
1	JUN	1500	31	2259.	2	JUN	0336	94	6675.	2	JUN	1612	157	27046.	3	JUN	0448	220	9141.
1	JUN	1512	32	2302.	2	JUN	0348	95	6818.	2	JUN	1624	158	26541.	3	JUN	0500	221	8907.
1	JUN	1524	33	2345.	2	JUN	0400	96	6962.	2	JUN	1636	159	26052.	3	JUN	0512	222	8695.
1	JUN	1536	34	2387.	2	JUN	0412	97	7092.	2	JUN	1648	160	25577.	3	JUN	0524	223	8483.
1	JUN	1548	35	2426.	2	JUN	0424	98	7221.	2	JUN	1700	161	25103.	3	JUN	0536	224	8322.
1	JUN	1600	36	2465.	2	JUN	0436	99	7345.	2	JUN	1712	162	24674.	3	JUN	0548	225	8213.
1	JUN	1612	37	2500.	2	JUN	0448	100	7462.	2	JUN	1724	163	24245.	3	JUN	0600	226	8103.
1	JUN	1624	38	2535.	2	JUN	0500	101	7579.	2	JUN	1736	164	23836.	3	JUN	0612	227	8103.
1	JUN	1636	39	2569.	2	JUN	0512	102	7689.	2	JUN	1748	165	23447.	3	JUN	0624	228	8103.
1	JUN	1648	40	2602.	2	JUN	0524	103	7799.	2	JUN	1800	166	23059.	3	JUN	0636	229	8103.
1	JUN	1700	41	2634.	2	JUN	0536	104	7916.	2	JUN	1812	167	22707.	3	JUN	0648	230	8103.
1	JUN	1712	42	2663.	2	JUN	0548	105	8039.	2	JUN	1824	168	22356.	3	JUN	0700	231	8103.
1	JUN	1724	43	2692.	2	JUN	0600	106	8162.	2	JUN	1836	169	22021.	3	JUN	0712	232	8103.
1	JUN	1736	44	2719.	2	JUN	0612	107	8322.	2	JUN	1848	170	21704.	3	JUN	0724	233	8103.
1	JUN	1748	45	2746.	2	JUN	0624	108	8482.	2	JUN	1900	171	21396.	3	JUN	0736	234	8103.
1	JUN	1800	46	2772.	2	JUN	0636	109	8666.	2	JUN	1912	172	21098.	3	JUN	0748	235	8103.
1	JUN	1812	47	2796.	2	JUN	0648	110	8873.	2	JUN	1924	173	20811.	3	JUN	0800	236	8103.
1	JUN	1824	48	2819.	2	JUN	0700	111	9080.	2	JUN	1936	174	20537.	3	JUN	0812	237	8103.

| | | |

HYDROGRAPH AT STATION OUT

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1	JUN	0900	1	0.	10310.0	6721.0	2	JUN	0148	85	4791.	10493.9	6724.2	2	JUN	1836	169	22212.	10720.7	6728.2
1	JUN	0912	2	36.	10314.1	6721.1	2	JUN	0200	86	5036.	10498.4	6724.3	2	JUN	1848	170	21885.	10717.6	6728.2
1	JUN	0924	3	68.	10317.9	6721.1	2	JUN	0212	87	5258.	10502.3	6724.4	2	JUN	1900	171	21583.	10714.5	6728.1
1	JUN	0936	4	100.	10321.6	6721.2	2	JUN	0224	88	5462.	10505.9	6724.5	2	JUN	1912	172	21297.	10711.2	6728.1
1	JUN	0948	5	133.	10325.4	6721.3	2	JUN	0236	89	5656.	10509.3	6724.5	2	JUN	1924	173	21009.	10708.0	6728.0
1	JUN	1000	6	168.	10329.5	6721.3	2	JUN	0248	90	5841.	10512.5	6724.6	2	JUN	1936	174	20727.	10704.8	6728.0
1	JUN	1012	7	209.	10334.2	6721.4	2	JUN	0300	91	6020.	10515.6	6724.6	2	JUN	1948	175	20458.	10701.7	6727.9
1	JUN	1024	8	255.	10339.6	6721.5	2	JUN	0312	92	6190.	10518.6	6724.7	2	JUN	2000	176	20196.	10698.7	6727.9
1	JUN	1036	9	308.	10345.7	6721.6	2	JUN	0324	93	6353.	10521.5	6724.7	2	JUN	2012	177	19946.	10695.8	6727.8
1	JUN	1048	10	366.	10352.5	6721.7	2	JUN	0336	94	6511.	10524.2	6724.8	2	JUN	2024	178	19708.	10693.1	6727.8
1	JUN	1100	11	429.	10359.8	6721.9	2	JUN	0348	95	6662.	10526.9	6724.8	2	JUN	2036	179	19476.	10690.5	6727.7
1	JUN	1112	12	503.	10367.6	6722.0	2	JUN	0400	96	6808.	10529.5	6724.9	2	JUN	2048	180	19256.	10688.0	6727.7
1	JUN	1124	13	622.	10375.3	6722.1	2	JUN	0412	97	6948.	10531.9	6724.9	2	JUN	2100	181	19042.	10685.5	6727.6
1	JUN	1136	14	735.	10382.5	6722.3	2	JUN	0424	98	7082.	10534.2	6725.0	2	JUN	2112	182	18830.	10683.1	6727.6
1	JUN	1148	15	841.	10389.4	6722.4	2	JUN	0436	99	7211.	10536.5	6725.0	2	JUN	2124	183	18619.	10680.7	6727.5
1	JUN	1200	16	943.	10395.9	6722.5	2	JUN	0448	100	7334.	10538.7	6725.0	2	JUN	2136	184	18401.	10678.2	6727.5
1	JUN	1212	17	1070.	10401.9	6722.6	2	JUN	0500	101	7453.	10540.8	6725.1	2	JUN	2148	185	18169.	10675.6	6727.4
1	JUN	1224	18	1260.	10406.5	6722.7	2	JUN	0512	102	7569.	10542.8	6725.1	2	JUN	2200	186	17928.	10672.8	6727.4
1	JUN	1236	19	1392.	10409.7	6722.8	2	JUN	0524	103	7681.	10544.8	6725.1	2	JUN	2212	187	17665.	10669.9	6727.3
1	JUN	1248	20	1494.	10412.2	6722.8	2	JUN	0536	104	7794.	10546.7	6725.2	2	JUN	2224	188	17377.	10666.6	6727.3
1	JUN	1300	21	1580.	10414.3	6722.8	2	JUN	0548	105	7911.	10548.8	6725.2	2	JUN	2236	189	17078.	10663.2	6727.2
1	JUN	1312	22	1657.	10416.1	6722.9	2	JUN	0600	106	8041.	10550.8	6725.3	2	JUN	2248	190	16761.	10659.5	6727.2
1	JUN	1324	23	1727.	10417.8	6722.9	2	JUN	0612	107	8195.	10552.9	6725.3	2	JUN	2300	191	16432.	10655.8	6727.1
1	JUN	1336	24	1794.	10419.5	6722.9	2	JUN	0624	108	8354.	10555.0	6725.3	2	JUN	2312	192	16098.	10652.0	6727.0
1	JUN	1348	25	1857.	10421.0	6723.0	2	JUN	0636	109	8522.	10557.2	6725.4	2	JUN	2324	193	15759.	10648.1	6727.0
1	JUN	1400	26	1918.	10422.5	6723.0	2	JUN	0648	110	8712.	10559.8	6725.4	2	JUN	2336	194	15420.	10644.3	6726.9
1	JUN	1412	27	1976.	10423.9	6723.0	2	JUN	0700	111	8915.	10562.4	6725.5	2	JUN	2348	195	15090.	10640.5	6726.9
1	JUN	1424	28	2031.	10425.2	6723.0	2	JUN	0712	112	9104.	10565.0	6725.5	3	JUN	0000	196	14766.	10636.8	6726.8
1	JUN	1436	29	2085.	10426.5	6723.1	2	JUN	0724	113	9274.	10567.2	6725.5	3	JUN	0012	197	14454.	10633.3	6726.7
1	JUN	1448	30	2136.	10427.8	6723.1	2	JUN	0736	114	9439.	10569.4	6725.6	3	JUN	0024	198	14158.	10629.9	6726.6
1	JUN	1500	31	2186.	10429.0	6723.1	2	JUN	0748	115	9605.	10571.6	6725.6	3	JUN	0036	199	13870.	10626.6	6726.6
1	JUN	1512	32	2232.	10430.2	6723.1	2	JUN	0800	116	9770.	10573.8	6725.7	3	JUN	0048	200	13595.	10623.5	6726.5
1	JUN	1524	33	2277.	10431.3	6723.1	2	JUN	0812	117	9931.	10575.9	6725.7	3	JUN	0100	201	13328.	10620.4	6726.5
1	JUN	1536	34	2320.	10432.4	6723.2	2	JUN	0824	118	10083.	10578.0	6725.7	3	JUN	0112	202	13073.	10617.5	6726.4
1	JUN	1548	35	2362.	10433.5	6723.2	2	JUN	0836	119	10377.	10581.9	6725.8	3	JUN	0124	203	12823.	10614.7	6726.4
1	JUN	1600	36	2403.	10434.5	6723.2	2	JUN	0848	120	10990.	10590.0	6725.9	3	JUN	0136	204	12618.	10611.7	6726.3
1	JUN	1612	37	2442.	10435.5	6723.2	2	JUN	0900	121	11820.	10601.1	6726.1	3	JUN	0148	205	12394.	10608.7	6726.3
1	JUN	1624	38	2479.	10436.5	6723.2	2	JUN	0912	122	12420.	10609.0	6726.3	3	JUN	0200	206	12175.	10605.8	6726.2
1	JUN	1636	39	2515.	10437.4	6723.2	2	JUN	0924	123	12637.	10612.6	6726.3	3	JUN	0212	207	11965.	10603.0	6726.2
1	JUN	1648	40	2549.	10438.3	6723.3	2	JUN	0936	124	12874.	10615.1	6726.4	3	JUN	0224	208	11763.	10600.3	6726.1
1	JUN	1700	41	2583.	10439.1	6723.3	2	JUN	0948	125	13048.	10617.2	6726.4	3	JUN	0236	209	11568.	10597.7	6726.1
1	JUN	1712	42	2615.	10439.9	6723.3	2	JUN	1000	126	13218.	10619.2	6726.5	3	JUN	0248	210	11383.	10595.3	6726.0
1	JUN	1724	43	2645.	10440.7	6723.3	2	JUN	1012	127	13376.	10621.0	6726.5	3	JUN	0300	211	11205.	10592.9	6726.0
1	JUN	1736	44	2675.	10441.5	6723.3	2	JUN	1024	128	13529.	10622.7	6726.5	3	JUN	0312	212	11027.	10590.5	6725.9
1	JUN	1748	45	2703.	10442.2	6723.3	2	JUN	1036	129	13679.	10624.4	6726.5	3	JUN	0324	213	10849.	10588.1	6725.9
1	JUN	1800	46	2730.	10442.9	6723.3	2	JUN	1048	130	13823.	10626.1	6726.6	3	JUN	0336	214	10663.	10585.7	6725.9
1	JUN	1812	47	2756.	10443.5	6723.4	2	JUN	1100	131	13965.	10627.7	6726.6	3	JUN	0348	215	10465.	10583.1	6725.8
1	JUN	1824	48	2781.	10444.2	6723.4	2	JUN	1112	132	14131.	10629.6	6726.6	3	JUN	0400	216	10257.	10580.3	6725.8
1	JUN	1836	49	2805.	10444.8	6723.4	2	JUN	1124	133	14325.	10631.8	6726.7	3	JUN	0412	217	10037.	10577.4	6725.7
1	JUN	1848	50	2828.	10445.4	6723.4	2	JUN	1136	134	14615.	10635.1	6726.7	3	JUN	0424	218	9802.	10574.2	6725.7
1	JUN	1900	51	2851.	10445.9	6723.4	2	JUN	1148	135	15102.	10640.6	6726.8	3	JUN	0436	219	9555.	10571.1	6725.6
1	JUN	1912	52	2872.	10446.5	6723.4	2	JUN	1200	136	15711.	10647.6	6727.0	3	JUN	0448	220	9330.	10568.0	6725.6
1	JUN	1924	53	2893.	10447.0	6723.4	2	JUN	1212	137	16906.	10660.1	6727.2	3	JUN	0500	221	9035.	10564.9	6725.5
1	JUN	1936	54	2913.	10447.5	6723.4	2	JUN	1224	138	18447.	10678.8	6727.5	3	JUN	0512	222	8870.	10561.9	6725.4
1	JUN	1948	55	2932.	10448.0	6723.4	2	JUN	1236	139	20348.	10700.4	6727.9	3	JUN	0524	223	8654.	10559.0	6725.4
1	JUN	2000	56	2950.	10448.5	6723.4	2	JUN	1248	140	22744.	10725.7	6728.3	3	JUN	0536	224	8451.	10556.4	6725.3

1	JUN	2000	56	2950.	10448.3	6723.4	*	2	JUN	1248	140	22744.	10725.7	6728.3	*	3	JUN	0536	224	8461.	10556.4	6725.3
1	JUN	2012	57	2968.	10448.9	6723.4	*	2	JUN	1300	141	25461.	10751.3	6728.8	*	3	JUN	0548	225	8313.	10554.4	6725.3
1	JUN	2024	58	2984.	10449.4	6723.5	*	2	JUN	1312	142	27709.	10772.5	6729.2	*	3	JUN	0600	226	8194.	10552.9	6725.3
1	JUN	2036	59	3001.	10449.8	6723.5	*	2	JUN	1324	143	29599.	10790.2	6729.5	*	3	JUN	0612	227	8124.	10551.9	6725.3
1	JUN	2048	60	3016.	10450.2	6723.5	*	2	JUN	1336	144	31090.	10804.4	6729.7	*	3	JUN	0624	228	8108.	10551.7	6725.3
1	JUN	2100	61	3031.	10450.5	6723.5	*	2	JUN	1348	145	31957.	10811.6	6729.8	*	3	JUN	0636	229	8104.	10551.7	6725.3
1	JUN	2112	62	3045.	10450.9	6723.5	*	2	JUN	1400	146	32220.	10815.0	6729.9	*	3	JUN	0648	230	8103.	10551.7	6725.3
1	JUN	2124	63	3059.	10451.3	6723.5	*	2	JUN	1412	147	32192.	10814.7	6729.9	*	3	JUN	0700	231	8103.	10551.7	6725.3
1	JUN	2136	64	3072.	10451.6	6723.5	*	2	JUN	1424	148	31774.	10810.8	6729.8	*	3	JUN	0712	232	8103.	10551.7	6725.3
1	JUN	2148	65	3085.	10451.9	6723.5	*	2	JUN	1436	149	31316.	10806.5	6729.8	*	3	JUN	0724	233	8103.	10551.7	6725.3
1	JUN	2200	66	3097.	10452.2	6723.5	*	2	JUN	1448	150	30829.	10801.9	6729.7	*	3	JUN	0736	234	8103.	10551.7	6725.3
1	JUN	2212	67	3109.	10452.5	6723.5	*	2	JUN	1500	151	30327.	10797.2	6729.6	*	3	JUN	0748	235	8103.	10551.7	6725.3
1	JUN	2224	68	3120.	10452.8	6723.5	*	2	JUN	1512	152	29828.	10792.5	6729.5	*	3	JUN	0800	236	8103.	10551.7	6725.3
1	JUN	2236	69	3131.	10453.1	6723.5	*	2	JUN	1524	153	29334.	10787.8	6729.4	*	3	JUN	0812	237	8103.	10551.7	6725.3
1	JUN	2248	70	3142.	10453.4	6723.5	*	2	JUN	1536	154	28838.	10783.1	6729.3	*	3	JUN	0824	238	8103.	10551.7	6725.3
1	JUN	2300	71	3152.	10453.6	6723.5	*	2	JUN	1548	155	28338.	10778.4	6729.3	*	3	JUN	0836	239	8103.	10551.7	6725.3
1	JUN	2312	72	3165.	10454.0	6723.5	*	2	JUN	1600	156	27836.	10773.7	6729.2	*	3	JUN	0848	240	8103.	10551.7	6725.3
1	JUN	2324	73	3136.	10454.5	6723.5	*	2	JUN	1612	157	27333.	10769.0	6729.1	*	3	JUN	0900	241	8103.	10551.7	6725.3
1	JUN	2336	74	3215.	10455.2	6723.6	*	2	JUN	1624	158	26829.	10764.2	6729.0	*	3	JUN	0912	242	8103.	10551.7	6725.3
1	JUN	2348	75	3250.	10456.4	6723.6	*	2	JUN	1636	159	26331.	10759.5	6728.9	*	3	JUN	0924	243	8103.	10551.7	6725.3
2	JUN	0000	76	3313.	10457.9	6723.6	*	2	JUN	1648	160	25848.	10755.0	6728.9	*	3	JUN	0936	244	8103.	10551.7	6725.3
2	JUN	0012	77	3398.	10459.9	6723.6	*	2	JUN	1700	161	25373.	10750.5	6728.8	*	3	JUN	0948	245	8103.	10551.7	6725.3
2	JUN	0024	78	3503.	10462.6	6723.7	*	2	JUN	1712	162	24920.	10746.2	6728.7	*	3	JUN	1000	246	8103.	10551.7	6725.3
2	JUN	0036	79	3628.	10465.8	6723.7	*	2	JUN	1724	163	24489.	10742.2	6728.6	*	3	JUN	1012	247	8103.	10551.7	6725.3
2	JUN	0048	80	3776.	10469.5	6723.8	*	2	JUN	1736	164	24070.	10738.2	6728.6	*	3	JUN	1024	248	8103.	10551.7	6725.3
2	JUN	0100	81	3943.	10473.8	6723.9	*	2	JUN	1748	165	23669.	10734.4	6728.5	*	3	JUN	1036	249	8103.	10551.7	6725.3
2	JUN	0112	82	4127.	10478.5	6724.0	*	2	JUN	1800	166	23280.	10730.8	6728.4	*	3	JUN	1048	250	8103.	10551.7	6725.3
2	JUN	0124	83	4327.	10483.6	6724.1	*	2	JUN	1812	167	22909.	10727.3	6728.4	*							
2	JUN	0136	84	4534.	10488.8	6724.2	*	2	JUN	1824	168	22556.	10724.0	6728.3	*							

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PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
(CFS)	(HR)		6-HR	24-HR	72-HR	49.80-HR
32220.	29.00	(CFS)	27356.	17159.	10338.	10389.
		(INCHES)	9.420	23.636	29.690	29.690
		(AC-FT)	13555.	34035.	42754.	42754.

PEAK STORAGE	TIME		MAXIMUM AVERAGE STORAGE			
(AC-FT)	(HR)		6-HR	24-HR	72-HR	49.80-HR
10815.	29.00		10769.	10659.	10559.	10559.

PEAK STAGE	TIME		MAXIMUM AVERAGE STAGE			
(FEET)	(HR)		6-HR	24-HR	72-HR	49.80-HR
6729.91	29.00		6728.80	6727.00	6725.21	6725.21

CUMULATIVE AREA = 27.00 SQ MI

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	IN	32413.	29.00	27380.	17160.	10447.	27.00		
ROUTED TO	OUT	32220.	29.00	27356.	17159.	10388.	27.00	6729.91	29.00

TABLE 1 STATION			IN FLOW	IN STAGE	OUT FLOW	OUT STAGE
PER	DAY MON	HRMN				
1	1 JUN	0900	260.00	0.0	0.0	6721.00
2	1 JUN	0912	274.40	0.0	35.50	6721.07
3	1 JUN	0924	288.80	0.0	68.19	6721.14
4	1 JUN	0936	322.20	0.0	99.71	6721.20
5	1 JUN	0948	374.60	0.0	132.75	6721.27
6	1 JUN	1000	427.00	0.0	163.36	6721.34
7	1 JUN	1012	515.40	0.0	208.60	6721.43
8	1 JUN	1024	603.80	0.0	255.23	6721.52
9	1 JUN	1036	696.60	0.0	307.71	6721.63
10	1 JUN	1048	793.80	0.0	365.84	6721.75
11	1 JUN	1100	891.00	0.0	429.16	6721.88
12	1 JUN	1112	981.90	0.0	502.67	6722.02
13	1 JUN	1124	1072.80	0.0	622.21	6722.15
14	1 JUN	1136	1160.20	0.0	734.83	6722.28
15	1 JUN	1148	1246.60	0.0	841.38	6722.40
16	1 JUN	1200	1329.00	0.0	942.88	6722.52
17	1 JUN	1212	1406.20	0.0	1069.91	6722.62
18	1 JUN	1224	1483.40	0.0	1260.05	6722.70
19	1 JUN	1236	1557.40	0.0	1392.10	6722.76
20	1 JUN	1248	1628.20	0.0	1493.87	6722.80
21	1 JUN	1300	1699.00	0.0	1579.95	6722.84
22	1 JUN	1312	1763.40	0.0	1656.65	6722.87
23	1 JUN	1324	1827.80	0.0	1727.09	6722.90
24	1 JUN	1336	1889.20	0.0	1793.71	6722.93
25	1 JUN	1348	1947.60	0.0	1856.93	6722.96
26	1 JUN	1400	2006.00	0.0	1917.70	6722.98
27	1 JUN	1412	2058.30	0.0	1975.85	6723.01
28	1 JUN	1424	2111.60	0.0	2031.30	6723.03
29	1 JUN	1436	2162.00	0.0	2084.79	6723.05
30	1 JUN	1448	2213.00	0.0	2136.09	6723.08
31	1 JUN	1500	2258.00	0.0	2185.51	6723.10
32	1 JUN	1512	2301.60	0.0	2231.64	6723.12
33	1 JUN	1524	2345.20	0.0	2276.55	6723.14
34	1 JUN	1536	2386.60	0.0	2320.30	6723.16
35	1 JUN	1548	2425.80	0.0	2362.35	6723.18
36	1 JUN	1600	2465.00	0.0	2403.02	6723.20
37	1 JUN	1612	2500.20	0.0	2441.36	6723.21
38	1 JUN	1624	2535.40	0.0	2479.06	6723.23
39	1 JUN	1636	2569.20	0.0	2514.91	6723.25
40	1 JUN	1648	2601.60	0.0	2549.41	6723.26
41	1 JUN	1700	2634.00	0.0	2582.37	6723.29
42	1 JUN	1712	2662.80	0.0	2614.96	6723.29
43	1 JUN	1724	2691.60	0.0	2645.42	6723.30
44	1 JUN	1736	2719.20	0.0	2674.78	6723.32
45	1 JUN	1748	2745.60	0.0	2702.97	6723.33
46	1 JUN	1800	2772.00	0.0	2730.28	6723.34
47	1 JUN	1812	2795.60	0.0	2755.45	6723.36
48	1 JUN	1824	2819.20	0.0	2781.37	6723.37
49	1 JUN	1836	2841.30	0.0	2805.40	6723.38
50	1 JUN	1848	2863.40	0.0	2828.49	6723.39

TABLE 1 (CONT.)

PER	DAY	MON	HRMN	STATION IN FLOW	IN STAGE	OUT FLOW	OUT STAGE
51	1	JUN	1900	2885.00	0.0	2850.86	6723.40
52	1	JUN	1912	2904.60	0.0	2872.35	6723.41
53	1	JUN	1924	2924.20	0.0	2892.83	6723.42
54	1	JUN	1936	2942.80	0.0	2912.77	6723.43
55	1	JUN	1948	2960.40	0.0	2931.75	6723.43
56	1	JUN	2000	2978.00	0.0	2950.08	6723.44
57	1	JUN	2012	2994.00	0.0	2967.62	6723.45
58	1	JUN	2024	3010.00	0.0	2984.43	6723.46
59	1	JUN	2036	3025.20	0.0	3000.66	6723.46
60	1	JUN	2048	3039.60	0.0	3016.18	6723.47
61	1	JUN	2100	3054.00	0.0	3031.15	6723.48
62	1	JUN	2112	3068.80	0.0	3045.44	6723.48
63	1	JUN	2124	3079.60	0.0	3059.01	6723.49
64	1	JUN	2136	3092.00	0.0	3072.08	6723.50
65	1	JUN	2148	3104.00	0.0	3084.72	6723.50
66	1	JUN	2200	3115.00	0.0	3097.06	6723.51
67	1	JUN	2212	3126.80	0.00	3109.97	6723.51
68	1	JUN	2224	3137.60	1.50	3120.32	6723.52
69	1	JUN	2236	3147.80	0.00	3131.25	6723.52
70	1	JUN	2248	3157.40	1.60	3141.69	6723.53
71	1	JUN	2300	3167.00	0.00	3151.70	6723.53
72	1	JUN	2312	3193.90	1.70	3165.72	6723.54
73	1	JUN	2324	3220.60	0.00	3186.02	6723.55
74	1	JUN	2336	3270.20	1.80	3215.07	6723.56
75	1	JUN	2348	3242.60	0.00	3259.77	6723.58
76	2	JUN	0000	3415.00	1.90	3315.03	6723.61
77	2	JUN	0012	3547.00	0.00	3397.81	6723.64
78	2	JUN	0024	3679.00	2.00	3503.18	6723.69
79	2	JUN	0036	3838.00	0.00	3623.20	6723.75
80	2	JUN	0048	4024.00	2.25	3770.46	6723.81
81	2	JUN	0100	4210.00	0.00	3943.22	6723.89
82	2	JUN	0112	4425.40	2.50	4126.86	6723.97
83	2	JUN	0124	4642.30	0.00	4326.56	6724.06
84	2	JUN	0136	4853.00	3.00	4534.14	6724.15
85	2	JUN	0148	5072.00	0.00	4780.66	6724.24
86	2	JUN	0200	5285.00	3.50	5035.92	6724.32
87	2	JUN	0212	5473.60	0.00	5258.21	6724.39
88	2	JUN	0224	5572.20	4.00	5462.12	6724.45
89	2	JUN	0236	5357.40	0.00	5656.41	6724.52
90	2	JUN	0248	6032.20	4.50	5841.20	6724.57
91	2	JUN	0300	6207.00	0.00	6019.59	6724.63
92	2	JUN	0312	6365.40	0.0	6190.44	6724.69
93	2	JUN	0324	6523.80	0.00	6353.28	6724.73
94	2	JUN	0336	6674.80	0.10	6510.91	6724.78
95	2	JUN	0348	6818.40	0.00	6661.94	6724.82
96	2	JUN	0400	6962.00	0.20	6808.24	6724.87
97	2	JUN	0412	7091.60	0.00	6943.29	6724.91
98	2	JUN	0424	7221.20	0.30	7061.64	6724.96
99	2	JUN	0436	7344.60	0.00	7210.59	6725.00
100	2	JUN	0448	7461.30	0.40	7334.02	6725.04

TABLE 1 (CONT.)

PER	DAY	MON	HRMN	STATION	IN FLOW	IN STAGE	OUT FLOW	OUT STAGE
101	2	JUN	0500		7579.00	0.00	7453.44	6725.07
102	2	JUN	0512		7689.00	0.50	7569.13	6725.11
103	2	JUN	0524		7799.00	0.00	7681.13	6725.14
104	2	JUN	0536		7915.50	0.60	7793.98	6725.18
105	2	JUN	0548		8033.80	0.00	7911.40	6725.21
106	2	JUN	0600		8162.00	0.70	8040.35	6725.25
107	2	JUN	0612		8322.00	0.00	8195.03	6725.29
108	2	JUN	0624		8482.00	0.80	8353.68	6725.32
109	2	JUN	0636		8565.60	0.00	8522.43	6725.36
110	2	JUN	0648		8372.60	0.90	8711.65	6725.41
111	2	JUN	0700		9080.00	0.00	8914.63	6725.45
112	2	JUN	0712		9243.50	1.00	9104.09	6725.50
113	2	JUN	0724		9407.20	0.00	9273.76	6725.54
114	2	JUN	0736		9572.00	1.10	9439.21	6725.58
115	2	JUN	0748		9736.00	0.00	9604.51	6725.61
116	2	JUN	0800		9904.00	1.20	9770.49	6725.65
117	2	JUN	0812		10054.40	0.00	9930.52	6725.69
118	2	JUN	0824		10204.80	1.30	10083.13	6725.73
119	2	JUN	0836		10728.00	0.00	10377.02	6725.80
120	2	JUN	0848		11624.00	3.10	10989.54	6725.94
121	2	JUN	0900		12520.00	0.00	11819.57	6726.13
122	2	JUN	0912		12585.20	3.20	12419.97	6726.27
123	2	JUN	0924		12350.40	0.00	12685.64	6726.34
124	2	JUN	0936		13012.40	3.32	12874.29	6726.38
125	2	JUN	0948		13171.20	0.00	13047.37	6726.42
126	2	JUN	1000		13330.00	3.41	13219.27	6726.45
127	2	JUN	1012		13488.00	0.00	13376.00	6726.48
128	2	JUN	1024		13634.00	3.52	13528.95	6726.52
129	2	JUN	1036		13780.40	0.00	13678.75	6726.55
130	2	JUN	1048		13921.20	3.62	13923.35	6726.57
131	2	JUN	1100		14062.00	0.00	13964.75	6726.61
132	2	JUN	1112		14282.00	3.71	14130.32	6726.64
133	2	JUN	1124		14462.00	0.00	14325.04	6726.68
134	2	JUN	1136		14677.00	3.80	14514.97	6726.73
135	2	JUN	1148		15510.00	0.00	15101.57	6726.83
136	2	JUN	1200		16142.00	3.83	15710.55	6726.95
137	2	JUN	1212		17589.60	0.00	16906.12	6727.18
138	2	JUN	1224		19523.20	3.94	18446.52	6727.50
139	2	JUN	1236		21783.60	0.00	20348.43	6727.89
140	2	JUN	1248		24263.30	4.00	22743.50	6728.34
141	2	JUN	1300		26933.00	0.00	25461.32	6728.79
142	2	JUN	1312		28793.40	4.04	27708.95	6729.15
143	2	JUN	1324		30647.30	0.00	29583.04	6729.47
144	2	JUN	1336		31742.60	4.07	31090.19	6729.72
145	2	JUN	1348		32077.80	0.00	31856.54	6729.85
146	2	JUN	1400		32413.00	4.09	32219.94	6729.91
147	2	JUN	1412		31967.40	0.00	32192.13	6729.91
148	2	JUN	1424		31521.80	0.0	31773.76	6729.84
149	2	JUN	1436		31047.20	0.00	31316.37	6729.75
150	2	JUN	1448		30543.60	0.01	30829.43	6729.69

TABLE 1 (CONT.)

PER	DAY	MON	HRMN	STATION	IN FLOW	IN STAGE	OUT FLOW	OUT STAGE
151	2	JUN	1500		30040.00	0.00	30326.88	6729.59
152	2	JUN	1512		29546.00	0.01	29827.84	6729.51
153	2	JUN	1524		29052.00	0.00	29333.53	6729.43
154	2	JUN	1536		28554.00	0.01	28837.64	6729.35
155	2	JUN	1548		28052.00	0.00	28337.91	6729.27
156	2	JUN	1600		27550.00	0.01	27836.06	6729.18
157	2	JUN	1612		27046.60	0.00	27332.94	6729.10
158	2	JUN	1624		26541.20	0.02	26828.64	6729.01
159	2	JUN	1636		26051.30	0.00	26331.18	6728.93
160	2	JUN	1648		25577.40	0.02	25848.32	6728.85
161	2	JUN	1700		25103.00	0.00	25373.34	6728.77
162	2	JUN	1712		24673.30	0.02	24920.04	6728.70
163	2	JUN	1724		24244.60	0.00	24489.29	6728.63
164	2	JUN	1736		23835.30	0.02	24069.52	6728.55
165	2	JUN	1748		23447.40	0.00	23669.50	6728.49
166	2	JUN	1800		23059.00	0.02	23280.39	6728.42
167	2	JUN	1812		22707.40	0.00	22909.11	6728.36
168	2	JUN	1824		22355.80	0.02	22556.22	6728.30
169	2	JUN	1836		22021.20	0.00	22212.45	6728.25
170	2	JUN	1848		21703.60	0.03	21885.20	6728.19
171	2	JUN	1900		21386.00	0.00	21583.35	6728.14
172	2	JUN	1912		21093.40	0.03	21296.52	6728.08
173	2	JUN	1924		20810.80	0.00	21009.00	6728.02
174	2	JUN	1936		20536.80	0.03	20727.16	6727.96
175	2	JUN	1948		20276.40	0.00	20457.61	6727.91
176	2	JUN	2000		20016.00	0.12	20195.79	6727.86
177	2	JUN	2012		19790.40	0.00	19945.57	6727.81
178	2	JUN	2024		19564.80	0.10	19707.61	6727.76
179	2	JUN	2036		19320.60	0.00	19476.47	6727.71
180	2	JUN	2048		19107.30	0.08	19255.95	6727.67
181	2	JUN	2100		18895.00	0.00	19041.39	6727.63
182	2	JUN	2112		18684.20	0.06	18829.71	6727.58
183	2	JUN	2124		18473.40	0.00	18618.70	6727.54
184	2	JUN	2136		18246.60	0.05	18401.12	6727.50
185	2	JUN	2148		18003.90	0.00	18169.14	6727.45
186	2	JUN	2200		17761.00	0.03	17923.02	6727.40
187	2	JUN	2212		17469.00	0.00	17564.84	6727.35
188	2	JUN	2224		17177.00	0.03	17377.43	6727.29
189	2	JUN	2236		16865.80	0.00	17073.08	6727.23
190	2	JUN	2248		16535.40	0.02	16760.67	6727.17
191	2	JUN	2300		16205.00	0.00	16432.38	6727.10
192	2	JUN	2312		15863.80	0.01	16097.73	6727.04
193	2	JUN	2324		15522.60	0.00	15757.62	6726.96
194	2	JUN	2336		15190.00	0.00	15420.19	6726.90
195	2	JUN	2348		14866.00	0.00	15090.43	6726.83
196	3	JUN	0000		14542.00	0.0	14765.55	6726.77
197	3	JUN	0012		14243.80	0.00	14454.34	6726.70
198	3	JUN	0024		13955.60	-0.01	14153.26	6726.64
199	3	JUN	0036		13675.20	0.00	13870.38	6726.59
200	3	JUN	0048		13410.60	-0.01	13595.47	6726.53

TABLE 1 (CONT.) STATION

PER	DAY	MON	HRMN	IN FLOW	IN STAGE	OUT FLOW	OUT STAGE
201	3	JUN	0100	13145.00	0.00	13323.34	6726.48
202	3	JUN	0112	12904.60	-0.01	13073.09	6726.43
203	3	JUN	0124	12664.20	0.00	12942.60	6726.38
204	3	JUN	0136	12436.20	0.00	12617.96	6726.32
205	3	JUN	0148	12217.60	0.00	12394.33	6726.27
206	3	JUN	0200	12000.00	0.03	12175.30	6726.22
207	3	JUN	0212	11801.20	0.00	11964.60	6726.17
208	3	JUN	0224	11602.40	0.05	11763.02	6726.12
209	3	JUN	0236	11415.00	0.00	11567.95	6726.07
210	3	JUN	0248	11239.00	0.07	11383.14	6726.03
211	3	JUN	0300	11063.00	0.00	11205.09	6725.99
212	3	JUN	0312	10883.80	0.09	11027.36	6725.95
213	3	JUN	0324	10704.60	0.00	10843.54	6725.91
214	3	JUN	0336	10509.80	0.11	10663.44	6725.86
215	3	JUN	0348	10299.40	0.00	10464.68	6725.82
216	3	JUN	0400	10089.00	0.12	10257.30	6725.77
217	3	JUN	0412	9850.20	0.00	10036.63	6725.71
218	3	JUN	0424	9611.40	0.14	9802.02	6725.66
219	3	JUN	0436	9375.00	0.00	9565.16	6725.61
220	3	JUN	0448	9141.00	0.15	9329.59	6725.55
221	3	JUN	0500	8907.00	0.00	9095.23	6725.50
222	3	JUN	0512	8695.00	0.16	8869.58	6725.44
223	3	JUN	0524	8483.00	0.00	8654.38	6725.39
224	3	JUN	0536	8322.20	0.17	8461.23	6725.35
225	3	JUN	0548	8212.60	0.00	8312.55	6725.31
226	3	JUN	0600	8103.00	0.18	8193.84	6725.29
227	3	JUN	0612	8103.00	0.00	8124.14	6725.27
228	3	JUN	0624	8103.00	0.19	8107.90	6725.27
229	3	JUN	0636	8103.00	0.09	8104.11	6725.26
230	3	JUN	0648	8103.00	0.19	8103.25	6725.26
231	3	JUN	0700	8103.00	0.00	8103.05	6725.26
232	3	JUN	0712	8103.00	-0.01	8103.01	6725.26
233	3	JUN	0724	8103.00	0.00	8102.96	6725.26
234	3	JUN	0736	8103.00	0.02	8102.96	6725.26
235	3	JUN	0748	8103.00	0.00	8102.96	6725.26
236	3	JUN	0800	8103.00	0.04	8102.96	6725.26
237	3	JUN	0812	8103.00	0.00	8102.96	6725.26
238	3	JUN	0824	8103.00	0.06	8102.96	6725.26
239	3	JUN	0836	8103.00	0.00	8102.96	6725.26
240	3	JUN	0848	8102.00	0.07	8102.96	6725.26
241	3	JUN	0900	8103.00	0.00	8102.96	6725.26
242	3	JUN	0912	8103.00	0.08	8102.96	6725.26
243	3	JUN	0924	8103.00	0.00	8102.96	6725.26
244	3	JUN	0936	8103.00	0.09	8102.96	6725.26
245	3	JUN	0948	8103.00	0.00	8102.96	6725.26
246	3	JUN	1000	8103.00	0.09	8102.96	6725.26
247	3	JUN	1012	8103.00	0.00	8102.96	6725.26
248	3	JUN	1024	8103.00	0.10	8102.96	6725.26
249	3	JUN	1036	8103.00	0.00	8102.96	6725.26
250	3	JUN	1048	8103.00	0.10	8102.96	6725.26
			MAX	32413.00	4.50	32219.94	6729.91
			MIN	260.00	-0.01	0.0	6721.00
			AVE	10421.95	0.38	10362.68	6725.19

EXHIBIT G

SOILS DATA

Bozeman silt loam.—The surface layer of Bozeman silt loam is very dark grayish-brown somewhat laminated or fine granular silt loam from 8 to 12 inches thick. The 5- or 6-inch subsurface layer is medium-brown fine silt loam or silty clay loam, that is rather compact, coarsely granular, and faintly prismatic. Below this material, the subsoil is yellowish-brown silty clay loam which in most places is rather friable and porous. In some places, however, as near the city limits of Bozeman, the material in this layer is brown, hard, compact, prismatic silty clay. Beginning at a depth ranging from 20 to 30 inches below the surface the lower subsoil layer is light-gray coarse silt loam which is very calcareous.

This soil occurs almost exclusively in the vicinity of Bozeman. It appears to be developed over the silty material of the "Bozeman lake beds." Conditions have been somewhat more favorable for the accumulation of organic matter here than in other parts of the valley, and a dark-colored soil has resulted. The surface relief of Bozeman silt loam is generally smooth and very favorable to cultivation. On the borders of areas of this soil, as south of Montana State College, some poorly drained land has resulted on account of springs coming to the surface at these points, but this is not a usual feature of the typical soil.

On the nonirrigated land, grain is grown almost exclusively, except on the Fort Ellis Experimental Farm about 3 miles east of Bozeman, where one cutting of alfalfa has been obtained without irrigation. Where irrigated, timothy produces a tonnage about equal to that of alfalfa. Some exceptionally high yields of grain also have been obtained.

The deep, fairly compact, silty character of this soil, together with its northern-slope exposure, does not facilitate warming up early in the spring, hence bacterial action and, consequently, nitrification are somewhat retarded.

Bozeman silt loam, brown phase.—The brown phase of Bozeman silt loam is intermediate in development between the darker colored Bozeman silt loam and the lighter colored Amsterdam silt loam, all these soils being derived from essentially the same kind of material. The 8- or 10-inch topsoil of this phase of the Bozeman soil is deep-brown silt loam. The subsurface soil is light-brown or yellowish-brown friable coarsely granular silt loam, in most places somewhat prismatic. The upper part of the subsoil is light-brown very friable noncalcareous silt loam, and the lower part, below a depth of 20 or 24 inches, is gray highly calcareous friable porous very fine sandy loam. Below a depth of 3 feet, the material is uniform light grayish-brown very fine sandy loam.

The general surface relief ranges from gently sloping to rolling. The steeply rolling untillable areas are separated and are included with the miscellaneous classification of rough broken and mountainous land. Much of this soil lies at an elevation of more than 5,000 feet above sea level.

This soil is rather widely distributed in the southern and eastern parts of the Gallatin Valley, and it is an important agricultural soil. The principal areas are on Goochs Ridge between Middle Creek and Cottonwood Creek. Scattered areas lie south of Gallatin Gateway north of Bridger Creek on the slopes of the Bridger Range, and west of Bozeman bordering the Middle Creek bottoms.

The areas north of Bridger Creek paralleling the Bridger Range are for the most part nonirrigable and for this reason are largely used for the production of winter wheat. On the irrigable areas, grain crops are ordinarily alternated with forage crops. Alfalfa yields appear to be somewhat better at the lower elevations than in the higher areas bordering the mountains, owing in part, perhaps, to the fact that the soil warms up earlier at the lower elevations, thus promoting bacterial activity. Bordering the mountains at the higher elevations, the lime zone lies at a greater depth beneath the surface. The nitrogen content ranges from 0.092 to 0.138 percent, or from about 3,220 to 5,830 pounds per acre-foot.

Huffine silt loam.—The Huffine soils, of which the silt loam is of the greatest extent and value, extend in an area, ranging from 4 to 5 miles in width, west of Bozeman and south nearly to the Gallatin Range. These soils are somewhat variable as to their content of gravel in the surface soil, depth to the gravel subsoil or substratum, and also as to the degree of drainage and depth to ground water at different seasons of the year.

On the eastern border of the experiment station plats, the 9- or 10-inch surface layer is dark-brown silt loam which grades below into

compact silty clay loam. Spots of the heavy silty clay loam appear at the surface in places, owing to leveling and washing of the surface soil by irrigation water, and they are distinctly noticeable, both in handling the soil and in crop growth. Below a depth of 15 or 16 inches, the subsoil becomes slightly calcareous yellowish-brown silty clay loam. Below a depth of about 20 inches, the calcareous material gives the subsoil a light grayish-brown color. Gravel layers over the entire area may range from 2 to 4 feet below the general land surface. Where the gravel layers are nearer to the surface, there is a corresponding shallowness in the overlying soil layers.

The surface relief of Hufline silt loam is, in general, fairly smooth, and the land slopes toward the north. Many shallow sloughs or drainageways, having a general northerly direction, traverse the area. These drainageways carry much water during the spring and summer, especially during the irrigation season. It has been noted that the ground-water level is highest early in June, during heavy irrigation of fields to the south.[3] A number of roadside ditches have been constructed, so that much of the ground water is picked up and directed to the larger stream channels. Although surface drainage of this area is generally fairly good, except in the lower sloughs, the water table fluctuates, depending on the amount of irrigation necessary, and in places it limits the growth of alfalfa. In the better drained areas and deeper soils, yields ranging from 4 to 5 tons are obtained. Yields of spring wheat under irrigation on this soil may range from 45 to 60 bushels an acre, depending somewhat on soil preparation and the extent of weed infestation. Good yields of oats and barley are also obtained under similar conditions. Acre yields on the experimental plats have averaged around 120 bushels of oats and 80 bushels of barley.

Hufline silt loam, poorly drained phase.—The poorly drained phase of Hufline silt loam includes all the shallow sloughs, depressions, or drainageways, through which much of the waste water from seepage and overirrigation passes, also the broad low flats where the ground water collects during the irrigation season.

The soil material of this phase is much the same as that of the typical soil, but there are greater variations. The surface soil in most places is darker, and in many places it is shallower and more gravelly. The gravel layer lies relatively nearer the surface. In some areas, as northeast of Rea School, silty material has collected, and the dark organic soil is deeper than normal, and in places a sticky clay has been deposited over the gravel. This clay becomes rather impervious and allows but little percolation, therefore the only means of escape of the excess water is through openings that may be provided. It is fortunate that these soils in general do not contain excessive quantities of troublesome alkali salts.

This soil for the most part is utilized only for grazing. Where the land does not become boggy and the water table does not come within a few feet of the surface, some excellent pastures may be maintained. Bluegrass, timothy, redtop, and the wheat grasses grow here, depending somewhat on the degree of drainage afforded.

Hufline gravelly loam.—Several small areas of Hufline gravelly loam occur in this area, mainly southwest of Bozeman. The surface soil to a depth of about 8 inches is dark grayish-brown loam containing a small percentage of small gravel. Below this the color changes gradually, and at a depth ranging from 15 to 18 inches it becomes grayish brown. The material gradually becomes sandier and the percentage of gravel increases with depth. At a depth ranging from 20 to 24 inches there is a mass of gravel embedded in nearly white calcareous fine sandy loam or silt loam. Over a large part of this soil, the profile does not differ from that of Hufline silt loam except in the larger percentage of gravel in the surface soil and subsoil.

This soil occurs in low areas along streams or at the heads of streams. Drainage is deficient, and in places the land is water-logged a large part of the year.

The agricultural value of this land is slightly lower than that of Hufline silt loam.

EXHIBIT H

DATA FROM TOXIC RETURN FLOW INVESTIGATION, MIDDLE CREEK DAM PROJECT, GALLATIN COUNTY, MONTANA

EXHIBIT H-1

LOGS OF SELECTED U.S. GEOLOGICAL SURVEY TEST HOLES LOCATED IN VICINITY OF SELECTED WELLS, GALLATIN COUNTY, MONTANA

USGS TEST HOLE D1-5-34CC2

(LOCATION: SW 1/4 SW1/4 Sec. 34, T.1S., R.5E.)

D1-5-34cc2

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zones, 10–39 ft, 60–83 ft, and 103–120 ft. Depth to water for top zone, 10 ft]

Quaternary (fan alluvium):		
Silt, buff	9	9
Gravel, silty, sandy; composed chiefly of volcanic and metamorphic rocks	30	39
Clay, sandy, silty, buff	23	62
Sand, poorly sorted; contains pebbles. The sand is composed chiefly of quartz with some biotite	21	83
Silt, clayey, buff	20	103
Gravel, silty; contains pebbles	12	115
Sand, medium to fine, silty; contains pebbles	12	127
Tertiary:		
Volcanic ash, gray	4	131
Siltstone, sandy, calcareous, tuffaceous, buff	9	140
Sand, medium to coarse, silty; contains pebbles.	14	154
Siltstone, sandy, calcareous, tuffaceous, buff	90	244
Gravel; composed of volcanic and metamorphic rocks	3	247
Silt, buff; contains pebbles	3	250

USGS TEST HOLE D2-5-14ac

(LOCATION: SW1/4 NE1/4 Sec. 14, T.2S., R.5E.)

D2-5-14ac

[Drilled by contractor for the U. S. Geological Survey. Principal water-bearing zone, 6.5–115 ft. Depth to water, 6.5 ft]

Quaternary (fan alluvium):		
Loam	4	4
Gravel, sandy, calcareous; gravel is composed of subangular to subrounded fragments of gneiss and volcanic rocks	6	10
Gravel, sandy and silty, calcareous	15	25
Sand; contains pebbles	2	27
Gravel, medium, sandy	28	55
Sand; contains pebbles	2	57
Gravel, medium, sandy	10	67
Clay, light-brown	.5	67.5
Gravel, medium, sandy	27.5	95
Gravel, sandy and slightly silty	20	115
Gravel, sandy, silty, and clayey. The amount of clay increases downward	30	145
Sand, fine, silty, interbedded with brown clay	10	155
Tertiary(?):		
Sand, silty, clayey; contains pebbles	30	185
Silt, clayey; interbedded with silty clay	25	210
Sand, silty; contains pebbles	4	214
Gravel, sandy; contains cobbles	2	216
Sand; contains pebbles	8	224
Silt and clay, buff; contains magnetite from 250–265 ft	41	265

Data Source: Hackett, O.M. 1960. Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana. U.S. Geological Survey Water Supply Paper 1482. U.S. Government Printing Office, Washington, D.C.

8M087.121/WPWATRES364
DRAFT 3/27/87

EXHIBIT H-2

SUMMARY OF DATA, CLARK WELL

EXHIBIT H-2.1

LITHOLOGIC AND COMPLETION LOG OF CLARK WELL

031 1S 5E 21 Gallatin CODED

Form No. 603 R9/82

File No. _____

WELL LOG REPORT

State law requires that this form be filed by the water well driller within 60 days after completio 006991

1. WELL OWNER
Name Thos. & Face Clark

2. CURRENT MAILING ADDRESS
Sakajawea Dr
Bozeman, Mt 59715

3. WELL LOCATION
County Gallatin
Township _____ N/S Range _____ E/W
_____ ¼ _____ ¼ _____ ¼ Section _____
Lot 15 Block _____
Subdivision Mountain View #5

4. PROPOSED USE Domestic ☒ Stock ☐ Irrigation ☐
Other ☐ specify _____

5. DRILLING METHOD _____ cable, _____ bored,
X forward rotary, _____ reverse rotary, _____ jetted,
_____ other (specify) _____

6. WELL CONSTRUCTION AND COMPLETION

Size of drilled hole	Size and weight of casing	From (feet)	To (feet)	Perforations _____ and/or Screen _____ Kind Size	From (feet)	To (feet)
5"	6" 18#/ft	0	67			

Was casing left open end? X Yes ___ No
Was a packer or seal used? ___ Yes X No
If so, what material _____
Was the well gravel packed? ___ Yes X No
Was the well grouted? ___ Yes X No
To what depth? _____
Material used in grouting Dirt mud
Well head completion: Pitless adapter
X Yes ___ No
Top of casing 12 in. or greater above grade
X Yes ___ No

7. WHAT IS THE TEMPERATURE OF THE WATER?
49 Degrees Fahrenheit
☐ Measured ☒ Estimated

8. WATER LEVEL
Static water level 12 feet below land surface
If flowing; closed-in pressure _____ psi
_____ gpm
Controlled by: _____ valve, _____ reducers,
_____ other, (specify) _____

9. WELL TEST DATA X pump ___ bailer
___ other, (specify) _____
Pumping level below land surface:
55 ft. after 1 hrs. pumping 30 gpm
_____ ft. after _____ hrs. pumping _____ gpm

10. WAS WELL PLUGGED OR ABANDONED? ___ Yes X No
If yes, how? _____

11. DATE COMPLETED 1-5-83

12. WELL LOG

Depth (ft.) From	To	Formation
0	2	top Soil
2	9	Clay
9	69	gravel

(use separate sheet if necessary)

13. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.
2-2-83
Date
Haggerty Drilling
Firm Name
2310 Fairway Dr. Bozeman
Address
Signature _____ 352
License No.

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION DNRC
32 SOUTH EWING HELENA, MONTANA 59620 449-3962

DEPARTMENT — BUREAU COPY

HKM ASSOCIATES
ENGINEERS · PLANNERS

EXHIBIT H-2.2

SUMMARY OF FIELD DATA ACQUIRED DURING WELL PURGING
AND SAMPLING OPERATIONS ON CLARK WELL, MARCH 12, 1987

CLARK WELL

LOCATION: SE1/4 NE1/4 Sec. 21, T.1S., R.5E.

STATIC WATER LEVEL: 13.2 feet from top of casing, 09:17, 3/12/87 (Top of casing 0.89 feet above land surface).

SAMPLING METHOD: Used existing well pump and sampled from hose attached to lawn and garden irrigation spigot near well.

SUMMARY: Let faucet run for approximately 69 minutes at a rate ranging between 5.5 and 5.8 gallons per minute before taking sample for laboratory analysis.

Time	Temperature (°C)	Conductivity (umhos/cm @ 25°C)	pH	Flow (gpm)	Remarks
09:21	---	---	---	5.8	Faucet on
09:30	9.8	550	---	5.8	Faucet on
09:39	9.8	550	6.9	---	Faucet on
09:42	---	---	---	5.5	Faucet on
10:05	9.9	560	7.1	---	Faucet on
10:09	---	---	---	5.5	Faucet on
10:20	10.0	560	6.9	---	Faucet on
10:30	---	---	---	5.8	Sampled for laboratory analysis
10:42	---	---	---	---	Faucet off

EXHIBIT H-2.3

RESULTS OF LABORATORY ANALYSIS OF WATER
QUALITY SAMPLE TAKEN MARCH 12, 1987 FROM CLARK WELL

ENERGY LABORATORIES

ENERGY LABORATORIES, INC.

P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

RECEIVED
MAR 26 1987
HKM Associates

LABORATORY REPORT

To: HKM Associates (1) Lab No.: 87-2604
Address: PO Box 31318 Date: 3-24-87 tab
Billings, Montana 59107
ATTN: Jim McGill

SPECIAL WATER ANALYSIS

Clark Well
Sampled 3-12-87 @ 1030
Samples Submitted 3-13 87

CONSTITUENT	mg/l
Carbonate	0
Potassium	2
Sodium	13
Calcium	80
Magnesium	20
Sulfate	25
Chloride	8
Alkalinity as CaCO3	261
Specific Conductance @ 25°C	564 umhos/cm
pH	7.5 s.u.
Ammonia as NH3	<0.1
Nitrate + Nitrite as N	1.80
Phosphorus as P	0.03
Fluoride	0.15
METALS (dissolved):	
Aluminum	<0.02
Antimony	0.01
Arsenic	<0.005
Barium	<0.10
Beryllium	<0.005
Boron	<0.10
Cadmium	<0.001
Chromium	<0.02
Copper	<0.01
Iron	<0.05
Lead	<0.02
Manganese	<0.02
Mercury	<0.001
Nickel	<0.01
Selenium	0.007
Silver	<0.005
Thallium	<0.01
Zinc	0.02

EXHIBIT H-3

SUMMARY OF DATA, LEAVERTON WELL

EXHIBIT H-3.1

LITHOLOGIC AND COMPLETION LOG OF LEAVERTON WELL

T1S R5E SEC 27 265-9 4111

GW 1 Revised 1969

STATE OF MONTANA
ADMINISTRATOR OF GROUNDWATER CODE
MONTANA WATER RESOURCES BOARD

NOTICE OF COMPLETION OF GROUNDWATER APPROPRIATION BY MEANS OF WELL

Developed after January 1, 1962

(Under Chapter 237 Montana Session Laws, 1961, as amended)

This form to be prepared by driller, and three copies to be filed by the owner with the County Clerk and Recorder in the county in which the well is located, last copy to be retained by driller.

Please answer all questions. If not applicable, so state, otherwise the form may be returned.

Owner Robert L. Heiser

Address Route 1, Box 239A

Bozeman, Mont. 59715

Date well started June 15, 1973

completed June 18, 1973

For Administrator's Use
File
GW 1

Type of well Drilled (Dug, driven, bored or drilled)

Equipment used Churn Drill (Cable drill, rotary or other)

Water Use: Domestic ☒ Municipal ☐ Stock ☐ Irrigation ☐

Industrial ☐ Drainage ☐ Other ☐* Garden/Lawn ☐

*Describe

USE: If used for irrigation, industrial, drainage or other. Explain, state number of acres and location or other data (i.e. Lot, Block and Addition).

ESTIMATED ANNUAL WITHDRAWAL

Size of Drilled Hole	Size and Weight of Casing	From (Feet)	To (Feet)	PERFORATIONS Kind Size	From (Feet)	To (Feet)
6"	6.5/8 OD x 17#	1' above ground	41	perf ----	---	---

N

W E

Lot 4, Valley Center Sub.
E½ NW¼ Sec 27
T 1 S R 5 E

Static water level 12 ft.*
Pumping water level 41 ft.*
at 30 gallons per minute,
measured 60 minutes after pumping began.
*Measured from ground level.
Well developed by Pump
for 1 hours.
Power Pump HP
Remarks: (Gravel packing, cementing, packers, type of shutoff)

INDICATE LOCATION OF WELL AND PLACE OF USE, IF POSSIBLE.
EACH SMALL SQUARE REPRESENTS 40 ACRES.

County Gallatin

DRILLER'S LOG

Indicate the character, color, thickness of strata such as soft, clay, sand, gravel, shale, sandstone, etc. Show depth at which water is found and height to which water rises in well.

Top of Ground (Elev. above sea level)

From (Feet)	To (Feet)	
0	2	Top Soil
2	18	Gravel
18	20	Sand
20	30	Sand & Gravel
30	31	Sand
31	41	Sand & Fine Gravel

HKM ASSOCIATES
ENGINEERS · PLANNERS

EXHIBIT H-3.2

SUMMARY OF FIELD DATA ACQUIRED DURING
WELL PURGING AND SAMPLING OPERATIONS
ON LEAVERTON WELL, MARCH 11, 1987

LEAVERTON WELL

LOCATION: NW1/4 NE1/4 NW1/4 Sec. 27, T.1S., R.5E.

STATIC WATER LEVEL: Unavailable 3/11/87

SAMPLING METHOD: Used existing well pump and sampled from 50 foot long, 0.5 inch diameter hose, attached to outside faucet used for lawn irrigation.

SUMMARY: Let faucet run for approximately 72 minutes at a rate ranging between 4.9 and 5.5 gallons per minute before taking sample for laboratory analysis.

Time	Temperature (°C)	Conductivity (umhos/cm @ 25°C)	pH	Flow (gpm)	Remarks
15:10	---	---	---	---	Faucet on
15:20	10.0	500	---*	---	Faucet on
15:33	9.7	485	---*	5.1	Faucet on
15:48	9.6	485	---*	5.0	Faucet on
16:01	9.5	485	---*	5.1	Faucet on
16:09	9.5	485	---*	4.9	Faucet on
16:15	9.5	485	---*	4.9	Faucet on
16:22	9.5	485	---*	5.5	Sampled for laboratory analysis
16:30	---	---	---	---	Faucet off

*pH meter not functioning.

EXHIBIT H-3.3

RESULTS OF LABORATORY ANALYSIS OF WATER
QUALITY SAMPLE TAKE MARCH 11, 1987 FROM LEAVERTON WELL

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

LABORATORY REPORT

To: HKM Associates (1) Lab No.: 87-2605
Address: PO Box 31318 Date: 3-24-87 tab
Billings, Montana 59107
ATTN: Jim McGill

SPEECIAL WATER ANALYSIS

Leaverton Well
Sampled 3-11-87 @ 1622
Samples Submitted 3-13 87

CONSTITUENT	mg/l	
Carbonate	0	
Potassium	5	
Sodium	13	
Calcium	70	
Magnesium	18	
Sulfate	16	
Chloride	4	
Alkalinity as CaCO3	240	
Specific Conductance @ 25°C	501	umhos/cm
pH	7.6	s.u.
Ammonia as NH3	<0.1	
Nitrate + Nitrite as N	3.00	
Phosphorus as P	0.05	
Fluoride	0.15	

METALS (dissolved):

Aluminum	<0.02
Antimony	<0.01
Arsenic	<0.005
Barium	<0.10
Beryllium	<0.005
Boron	<0.10
Cadmium	<0.001
Chromium	<0.02
Copper	<0.01
Iron	<0.05
Lead	<0.02
Manganese	<0.02
Mercury	<0.001
Nickel	<0.01
Selenium	0.008
Silver	<0.005
Thallium	<0.01
Zinc	0.04

EXHIBIT H-4

SUMMARY OF DATA, BREKKE WELL

EXHIBIT H-4.1

LITHOLOGIC AND COMPLETION LOG OF BREKKE WELL

Form No. 603 R10/79 01S 05E 35 CC File No. GALLATIN

031

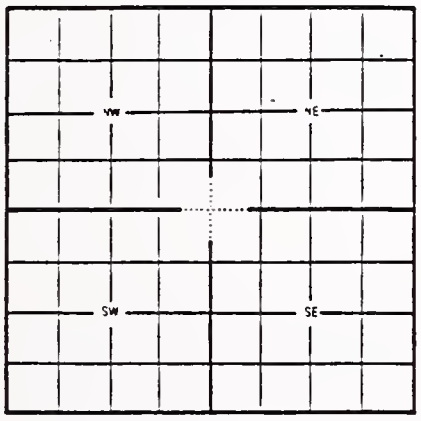
WELL LOG REPORT

State law requires that this form be filed by the water well driller within 60 days after completion of the well.

1. WELL OWNER
Name ~~L.J. Brakke~~

2. CURRENT MAILING ADDRESS
~~401 West Lamme~~
~~Bozeman, Montana~~

3. WELL LOCATION



W½ E ½ SW ¼ SW ¼ Section 35
Township 1S N/S Range 5E E/W
County Gallatin
Lot ____ Block ____
Subdivision ____
Well Elevation ____
Accuracy: ____ ±10'; ____ ±50'; ____ ±100';

4. DRILLING METHOD ____ cable, ____ bored, ____ forward rotary, ____ reverse rotary, ____ jetted, ____ other (specify) ____

5. WELL CONSTRUCTION AND COMPLETION

Size of drilled hole	Size and weight of casing	From (feet)	To (feet)	Perforations ____ and/or Screen ____ Kind Size	From (feet)	To (feet)
6"	6" 17#	+1'	46'1"			

Was casing left open end? x Yes ____ No
Was a packer or seal used? ____ Yes x No
If so, what material ____
Was the well gravel packed? ____ Yes x No
Was the well grouted? ____ Yes x No
To what depth? ____
Material used in grouting ____
Well head completion: Pitless adapter x
12 in. above grade x, other ____
(if other, specify) ____
Pump horsepower 7.4, pump type SUB
Pump intake level 42 feet below land surface
Power (electric, ~~diesel, etc.~~) ____

6. WATER LEVEL
Static water level = feet below land surface
If flowing, closed-in pressure ____ psi
____ gpm flow through ____ inch pipe
Controlled by: ____ valve, ____ reducers, ____ other
(if other, specify) ____

7. WELL TEST DATA ____ pump x bailer air other
(if other, specify) ____
Pumping level below land surface:
10 ft. after 2 hrs. pumping 40 gpm
____ ft. after ____ hrs. pumping ____ gpm

8. WAS WELL PLUGGED OR ABANDONED? ____ Yes x No
If yes, how? ____

9. DATE STARTED Sept. 8,1981
DATE COMPLETED Sept. ,1981

10. WELL LOG

Depth (ft.) From	To	Formation
0	3	topsoils
3	31	coarse overburden
31	36	sloppy sands
36	43	tight dirty sand and gravels
43	45	sand and gravels

(use separate sheet if necessary)

RECEIVED
DEC 22 1981
MONTANA D.N.R.C.
BOZEMAN FIELD OFFICE

11. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.
Sept. ,1981
Date
Potts Drilling and Developing
Firm Name
80730 Gallatin Road Bozeman, Montana
Address
Herbert A Potts 150
Signature License No.

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION DNRC
32 SOUTH EWING HELENA, MONTANA 59601 449-3634

DEPARTMENT COPY

x air
WL - 5917

HKM ASSOCIATES
ENGINEERS · PLANNERS

EXHIBIT H-4.2

SUMMARY OF FIELD DATA ACQUIRED DURING WELL PURGING
AND SAMPLING OPERATIONS ON BREKKE WELL, MARCH 12, 1987

BREKKE WELL

LOCATION: E1/2 SW1/4 SW1/4 Sec. 35, T.1S., R.5E.

STATIC WATER LEVEL: 6.21 feet from top of casing, 11:19, 3/12/87 (Top of casing 1.88 feet above land surface)

SAMPLING METHOD: Used existing well pump and sampled from 50 foot long, 0.5 inch diameter hose, attached to outside faucet on house used for lawn irrigation.

MISCELLANEOUS INFORMATION: Homeowner utilizes separate shallow well constructed of 1.55 feet galvanized steel culvert for lawn irrigation. Total depth of shallow well is approximately 7.26 feet from land surface and the static water level in the well as measured at 11:12, 3/12/86 ws 4.4 feet from land surface.

SUMMARY: Let faucet run for approximately 67 minutes at a rate ranging between 6.2 and 7.5 gallons per minute before taking sample for laboratory analysis.

8M087.121/WPWATRES364

Time	Temperature (°C)	Conductivity (umhos/cm @ 25°C)	pH	Flow (gpm)	Remarks
11:24	---	---	---	---	Faucet on
11:38	---	---	---	6.2	Faucet on
11:41	9.0	500	6.9	---	Faucet on
11:51	8.5	445	7.0	7.5	Faucet on
12:11	8.5	500	7.1	7.5	Faucet on
12:31	8.5	500	7.1	7.5	Sampled for laboratory analysis
12:40	---	---	---	---	Faucet off

EXHIBIT H-4.3

RESULTS OF LABORATORY ANALYSIS OF WATER
QUALITY SAMPLE TAKEN MARCH 12, 1987 FROM BREKKE WELL

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

LABORATORY REPORT

To: HKM Associates (1) Lab No.: 87-2607
Address: PO Box 31318 Date: 3-24-87 tab
Billings, Montana 59107
ATTN: Jim McGill

SPEECIAL WATER ANALYSIS

L.J. Brekke Well
Sampled 3-12-87 @ 1231
Samples Submitted 3-13-87

CONSTITUENT	mg/l	
Carbonate	0	
Potassium	4	
Sodium	14	
Calcium	73	
Magnesium	16	
Sulfate	10	
Chloride	5	
Alkalinity as CaCO3	250	
Specific Conductance @ 25°C	495	umhos/cm
pH	7.5	s.u.
Ammonia as NH3	<0.1	
Nitrate + Nitrite as N	1.27	
Phosphorus as P	0.05	
Fluoride	<0.10	
METALS (dissolved):		
Aluminum	<0.02	
Antimony	<0.01	
Arsenic	<0.005	
Barium	<0.10	
Beryllium	<0.005	
Boron	<0.10	
Cadmium	<0.001	
Chromium	<0.02	
Copper	<0.01	
Iron	<0.05	
Lead	<0.02	
Manganese	<0.02	
Mercury	<0.001	
Nickel	<0.01	
Selenium	0.003	
Silver	<0.005	
Thallium	<0.01	
Zinc	0.02	

EXHIBIT H-5

SUMMARY OF DATA, SWENSON WELL

EXHIBIT H-5.1

LITHOLOGIC AND COMPLETION LOG OF SWENSON WELL

FORM No. 603 New 7-75 031 025 05E 03D 031 025 05E 03 D File No. _____

Gallatin

STATE OF MONTANA
Department of Natural Resources and Conservation

WHITE — DEPARTMENT
PINK — BUREAU
CANARY — WELL OWNER
GOLDENROD — DRILLER

WELL LOG REPORT (2)

State law requires that this form be filed by the water well driller on any water well completed by him on and after July 1, 1973 within sixty (60) days after completion of the well.

1. WELL OWNER: Name Robert F. Swenson Address Route 4 - Box 23[illegible] - Bozeman, Mt.

2. WELL LOCATION: County Gallatin a tract of land in [illegible] Sec. 3, Twp. 2 N-S, Rg. 5 E-W

3. PROPOSED USE: X Domestic ___ Stock ___ Municipal ___ Industrial ___ Lawn and Garden ___ Irrigation ___ Other (*if other, specify*) _____

4. METHOD DRILLED: X Cable ___ Bored ___ Forward Rotary ___ Reverse Rotary ___ Jetted ___ Other (*if other, specify*) _____

5. WELL CONSTRUCTION:
Diameter of hole 6 inches. Depth 50 ft.
Casing: X Steel ___ Plastic ___ Concrete ___ Threaded X Welded ___ Other (*if other, specify*) _____
Pipe Weight:Dia.: From: To:
17 lb/ft. 6 5/8 inches above feet 50 feet
___ lb/ft. OD inches [illegible] feet ___ feet
___ lb/ft. ___ inches ___ feet ___ feet
Was perforated pipe used? ___ Yes X No
Length of pipe perforated _____ feet
Was casing left open end? X Yes ___ No
Was a well screen installed? ___ Yes X No
Material _____ Dia. ___ inches (*stainless steel, bronze, etc.*)
Perforation type: ___ slots ___ holes
Size ___ set from ___ feet to ___ feet
Size ___ set from ___ feet to ___ feet
Size ___ set from ___ feet to ___ feet
Was a packer or seal used? ___ Yes ___ No
If so, what material _____
Well type: ___ Straight screen ___ Graveled
Was the well grouted? ___ Yes X No
To what depth? _____ feet
Material used in grouting _____
Well head completion: Pitless adapter Yes
12" above grade X Other _____
(*If other, specify*) _____
Was the well disinfected? ___ Yes X No

6. WATER LEVEL:
Static water level 11 ft.below land surface
If flowing: closed-in pressure _____ psi
GPM flow _____ through _____ inch pipe
Controlled by: ___ Valve ___ Reducers ___ Other, *specify* _____

7. WELL TEST DATA: X Pump ___ Bailer ___ Other (*If other, specify*) _____
Pumping level below land surface:
[illegible] ft. after 2 hrs. pumping 25 gpm
_____ ft. after _____ hrs. pumping _____ gpm

8. WELL LOG:

Depth (ft.) From	To	Formation
0	3	Top Soil
3	38	Gravel
38	50	Sand & Gravel
50	52	Sand & Blue Gravel

(*Use separate sheet if necessary*)

9. DATE STARTED: Sept. 10, 1973

10. DATE COMPLETED: Sept. 15, 1973

11. WAS WELL PLUGGED OR ABANDONED? ___ Yes X No
If so, how _____

12. DRILLER'S CERTIFICATION:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Jones Welding & Drilling Co. 17
Driller's or Firm Name *License No.*

2102 Bridger Drive - Bozeman Montana
Address

Milton E. Jones 5/15/74
Signed by *Date*

HKA ASSOCIATES
ENGINEERS · PLANNERS

EXHIBIT H-5.2

SUMMARY OF FIELD DATA ACQUIRED DURING WELL PURGING
AND SAMPLING OPERATIONS ON SWENSON WELL, MARCH 12, 1987

SWENSON WELL

LOCATION: E1/2 SE1/4 Sec. 3, T.2S., R.5E.

STATIC WATER LEVEL: 12.1 feet from top of casing, 13:48, 3/12/87 (Top of casing 1.34 feet above land surface)

SAMPLING METHOD: Used existing well pump and sampled from 50 foot long, 0.5 inch diameter hose, attached to lawn and garden irrigation spigot near well.

SUMMARY: Let faucet run for approximately 52 minutes at approximately 20.4 gallons per minute before taking sample for laboratory analysis.

Time	Temperature (°C)	Conductivity (umhos/cm @ 25°C)	pH	Flow (gpm)	Remarks
13:50	---	---	---	---	Faucet on
14:01	---	---	---	20.4	Faucet on
14:06	8.5	450	7.0	20.4	Faucet on
14:25	8.0	450	6.8	---	Faucet on
14:35	8.0	460	6.8	---	Faucet on
14:42	8.5	460	6.8	20.4	Sampled for laboratory analysis
14:55	---	---	---	---	Faucet off

EXHIBIT H-5.3

RESULTS OF LABORATORY ANALYSIS OF WATER
QUALITY SAMPLE TAKEN MARCH 12, 1987 FROM SWENSON WELL

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

LABORATORY REPORT

To: HKM Associates (1) Lab No.: 87-2606
Address: PO Box 31318 Date: 3-24-87 tab
Billings, Montana 59107
ATTN: Jim McGill

SPEECIAL WATER ANALYSIS

R.J. Swenson Well
Sampled 3-12-87 @ 1442
Samples Submitted 3-13-87

CONSTITUENT	mg/l	
Carbonate	0	
Potassium	4	
Sodium	15	
Calcium	68	
Magnesium	14	
Sulfate	11	
Chloride	3	
Alkalinity as CaCO3	238	
Specific Conductance @ 25°C	465	umhos/cm
pH	7.6	s.u.
Ammonia as NH3	<0.1	
Nitrate + Nitrite as N	0.59	
Phosphorus as P	0.08	
Fluoride	0.14	
METALS (dissolved):		
Aluminum	<0.02	
Antimony	<0.01	
Arsenic	<0.005	
Barium	<0.10	
Beryllium	<0.005	
Boron	<0.10	
Cadmium	<0.001	
Chromium	<0.02	
Copper	<0.01	
Iron	<0.05	
Lead	<0.02	
Manganese	<0.02	
Mercury	<0.001	
Nickel	<0.01	
Selenium	0.002	
Silver	<0.005	
Thallium	<0.01	
Zinc	0.02	

EXHIBIT H-6

LABORATORY QUALITY ASSURANCE PROGRAM,
TOXIC RETURN FLOWS INVESTIGATION,
MIDDLE CREEK DAM PROJECT

EXHIBIT H-6.1

ENERGY LABS, INC., QUALITY ASSURANCE MANUAL

QUALITY ASSURANCE PROGRAM

WATER ANALYSIS

ENERGY LABORATORIES, INC.

1107 South Broadway

Billings, Montana 59107

Phone (406) 252-6325

1986

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CHAPTER 1

PREFACE

To be able to respond to the testing and research needs of industry and government, a commercial laboratory must be prepared to invest in sophisticated analytical instruments and a highly competent professional staff. A compromise in either one will compromise the quality of services offered. Inherent in quality testing services are precautionary steps taken by a professional staff to assure that test results reported are accurate and precise.

This manual was prepared to acquaint the reader with those testing checks routinely performed by the Energy Laboratories, Inc. staff to provide the highest degree of confidence in the test results reported.

The laboratory will, of course, follow prearranged quality criteria established by a client, in addition to, or in place of those performed routinely.

Energy Laboratories, Inc. is a private company dedicated to providing the highest caliber laboratory testing and research services to industry, government, engineering firms and private individuals. The analytical laboratory provides qualitative and quantitative data which is often used in a decision making process. To be valuable, the data must be accurate.

CHAPTER 2

LABORATORY FACILITIES

Laboratory space includes adequate bench-top space and floor space to accomodate periods of peak workloads. Working space includes sufficient bench-top area for processing samples; storage space for reagents, chemicals, glassware, bench and portable equipment items; floor space for stationary equipment and adequate associated area for cleaning glassware. The laboratory contains at least 15 linear feet of usable bench space per analyst, and 150 to 200 square feet per person.

The laboratory is located in a clean, well-lighted, well-ventilated building that is reasonably free of dust and draft and not subject to excessive temperature changes. A light intensity of 100 foot candles is present at all working sufaces. Ample cabinets, drawers and shelves are available for storage and protection of glassware.

The laboratory has provisions for the disposal of chemical wastes. Exhaust hoods are available for use in the preparation, extraction and analyses of samples where needed.

CHAPTER 3

LABORATORY PERSONNEL

Resumes of the laboratory personnel who will be involved in the testing and/or supervision of the water laboratory are presented in the appendix.

LABORATORY DIRECTOR

A. Education: Minimum of Bachelor of Science degree or its' equivalent.

B. Experience: Minimum of 5 years experience.

SUPERVISOR

A. Education: Minimum of Bachelors degree in chemistry or its' equivalent.

B. Experience: Minimum of 2 years of experience in measurements being considered for certification.

ANALYSTS

A. Education: Minimum of high school diploma or it's equivelant.

B. Experience: Minimum of 6 months on the job training, under direct supervision of qualified analyst, in the measurements being considered for certification.

C. After 6 months, the analyst must demonstrate acceptable skills through the successful participation in the analysis of applicable performance evaluation samples.

All personnel are advised to take advantage of courses and/or

workshops available from State and Federal regulatory agencies.

All personnel are required to utilize the safety tapes/slides and reading materials which are made available on a regular basis.

CHAPTER 4

SAMPLE COLLECTION

Most of the samples processed in this laboratory are collected by private individuals or companies who are responsible for using proper collection procedures. The staff is aquainted with proper collection and handling procedures and will advise those who need help in this area.

When the laboratory has been assigned the responsibility for sample collection, handling and preservation there is strict adherance to correct sampling procedures, complete sample identification, and prompt transfer of sample(s) to the laboratory.

The collection report form is completed immediately after collection of sample. Location, date and time of collection, collector's name, and any special remarks concerning the sample are recorded.

This laboratory provides proper sample containers and preservatives as required in the U.S. Environmental Protection Agency, METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES.

Samples received in unacceptable containers or improperly preserved are rejected and resampling is requested.

It is essential that all samples be analyzed within the maximum holding times. Samples are routinely analyzed within 2 weeks of their submittal date. When maximum holding times cannot be met, the sample is discarded and resampling is requested.

RECOMMENDATION FOR SAMPLING AND PRESERVATION OF SAMPLES ACCORDING TO MEASUREMENT, U.S.E.P.A. Methods for Chemical Analysis of Water and Wastes.

Measurement	Container (1)	Preservative (2,3)	Holding Time (4)
		PHYSICAL PROPERTIES	
Color	P,G	Cool	48 hours
Conductance	P,G	Cool	28 days
Hardness	P,G	HNO3 to pH <2	6 months
Odor	G	Cool	24 hours
pH	P,G	None Req.	Immed.
Residue			
Filterable	P,G	Cool	7 days
Non-Filterable	P,G	Cool	7 days
Total	P,G	Cool	7 days
Volatile	P,G	Cool	7 days
Settleable Matter	P,G	Cool	48 hours
Temperature	P,G	None Req.	Immed.
Turbidity	P,G	Cool	48 hours
		METALS	
Dissolved	P,G	Filter on site, pH <2	6 months
Suspended		Filter on site	6 months(7)
Total	P,G	HNO3 to pH <2	6 months
Chromium +6	P,G	Cool	24 hours
Mercury, dissolved	P,G	Filter, HNO3 to pH <2	28 days
Mercury, total	P,G	HNO3 to pH <2	28 days

INORGANICS, NON-METALICS

Acidity	P,G	Cool	14 days
Alkalinity	P,G	Cool	14 days
Bromide	P,G	None req.	28 days
Chloride	P,G	None req.	28 days
Chlorine	P,G	None req.	Immed.
Cyanides	P,G	Cool ,NaOH to pH >12(5)	14 days(6)
Fluoride	P,G	None req.	28 days
Iodide	P,G	Cool	24 hours
Nitrogen			
Ammonia	P,G	Cool , H2SO4 to pH <2	28 days
Kjeldahl, total	P,G	Cool , H2SO4 to pH <2	28 days
Nitrate + Nitrite	P,G	Cool , H2SO4 to pH <2	28 days
Nitrate(8)	P,G	Cool	48 hours
Nitrite	P,G	Cool	48 hours
Dissolved Oxygen			
Probe	G	None req.	Immed.
Winkler	G	Fix on site;store-dark	8 hours
Phosphorous			
Ortho-,diss.	P,G	Filter,Cool	48 hours
Hydrolyzable	P,G	Cool ,H2SO4 to pH <2	28 days
Total	P,G	Cool ,H2SO4 to pH <2	28 days
Dissolved	P,G	Filter,Cool ,H2SO4 pH <2	24 hours
Silica	P only	Cool	28 days
Sulfate	P,G	Cool	28 days
Sulfide	P,G	Cool , ZnOAc+NaOH to pH >9	7 days
Sulfite	P,G	None req.	Immed.

ORGANICS

BOD	P,G	Cool	48 hours
COD	P,G	Cool , H2SO4 to pH <2	28 days
Oil and Grease	G	Cool , H2SO4 to pH <2	28 days
Organic carbon	P,G	Cool , H2SO4 to pH <2	28 days
Phenolics	G	Cool , H2SO4 to pH <2	28 days
MBAS	P,G	Cool	48 hours
NTA	P,G	Cool	24 hours

1. Plastic(P) or Glass(G). For metals, polyethylene with a polypropylene cap (no liner) is preferred.

2. Sample preservation is performed immediately upon sample collection. For composite samples each aliquot is preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then samples are preserved by maintaining at 4 degrees C until compositing and sample splitting is completed.

3. When any sample is shipped by common carrier or sent through the United States Mails, it complies with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements above, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric Acid (HCL) in water solutions at concentrations of 0.04% by weight or less(pH of 1.96 or greater); Nitric Acid (HNO3) in water solutions at concentrations of 0.15% by weight or less (pH of 1.62 or greater); Sulfuric Acid (H2SO4) in water solutions at concentrations of 0.35% by weight or less (pH of 1.15 or greater); Sodium Hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH of 12.30 or less).

4. Samples are analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of sample under study are stable for the longer time, and has received a variance from the Regional Administrator. Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show this is necessary to maintain sample stability.

5. 0.6 g Ascorbic Acid to be used only in the presence of residual chlorine.

6. Maximum holding time is 24 hours when sulfide is present. Optionally, all samples are tested with lead acetate paper before the pH adjustment in order to determine if sulfide is present. If sulfide is present, it is removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

7. Samples for analysis of dissolved metals are filtered immediately on-site before adding preservative.

8. For samples from non-chlorinated drinking water supplies concentrated H_2SO_4 is added to lower sample pH to less than 2. The sample is analyzed within 14 days.

CHAPTER 5

LOGGING IN

1. All samples are logged into the laboratory log and given an Energy Laboratories, Inc. log number.

2. Samples that were preserved by the client are checked with pH paper to insure that sufficient quantities of preservative were added.

3. Samples received unpreserved and iced during transit are preserved immediately upon arrival at laboratory.

4. Collection report forms are checked and must contain pertinent data. If information is missing, collector is notified and missing information requested.

5. If samples are improperly preserved or maximum holding times are exceeded upon arrival at the laboratory, the collector is notified and resampling is reqested.

CHAIN OF CUSTODY

Occasionally we are requested to comply with a client's chain of custody procedure. Each client's requested procedure may be slightly different, but all have common elements. Appropriate information regarding sample time and date received are recorded on the chain of custody report form. Sample identification information is compared to be sure the report form matches the sample identification on the sample container. The sample is inspected and information regarding condition of sample and seal (if a seal is used) is recorded on report form. A copy of the chain of custody report form is kept with the sample data file, and a copy is sent to

the client with the analysis report.

CHAPTER 6

RECORDS AND DATA REPORTING

1. Records of chemical analyses are kept by the laboratory for not less than 5 years. This includes all raw data, calculations, and quality control data. More specifically this includes:

   a. Date, place and time of sampling; name of collector. (Client or Energy Laboratories, Inc.)

   b. Identification of sample as to whether it is a routine distribution system sample, check sample, raw or process water sample, or a special purpose sample.

   c. Submittal and analysis date of sample.

   d. Persons responsible for performing analysis.

   e. Analytical technique/method used.

   f. Results of analysis.

   g. Final report to client.

2. When action response is a designated laboratory responsibility, the proper authority is promptly notified of non-compliance sample results and a request is made for resampling from the same sampling point.

3. Report distribution:

   a. The client receives one copy (unless more requested) of results. These are mailed the same day they become available.

   b. If requested, one copy is sent to the Water Quality Bureau, County Sanitarian or Health Officer, or EPA Region 8. THIS REQUEST MUST BE FROM THE CLIENT.

   c. One copy is kept in our files. Each client has a separate file in the office.

CHAPTER 7

ANALYTICAL METHODOLOGY

Below is a list of the methods used in accordance with the Federal Register 40 CFR Part 136, October 26, 1984.

WATER ANALYSIS METHODS

Parameter	Method	Limit	Units
Aluminum	EPA 200.7	0.1	mg/l
Antimony	EPA 204.2	0.05	mg/l
Arsenic	EPA 206.2	0.005	mg/l
Arsenic, ICAP	EPA 200.7	0.05	mg/l
Barium	EPA 200.7	0.1	mg/l
Beryllium	EPA 200.7	0.005	mg/l
Boron	EPA 200.7	0.1	mg/l
Cadmium	EPA 200.7	0.001	mg/l
Calcium	EPA 200.7	1	mg/l
Chromium	EPA 200.7	0.02	mg/l
Chromium, hex.	EPA 218.4	0.02	mg/l
Cobalt	EPA 200.7	0.01	mg/l
Copper	EPA 200.7	0.01	mg/l
Gold	EPA 200.7	0.01	mg/l
Iron	EPA 200.7	0.03	mg/l
Lead	EPA 239.2	0.01	mg/l
Lead	EPA 200.7	0.04	mg/l
Lithium	EPA 200.7	0.01	mg/l
Magnesium	EPA 200.7	1	mg/l
Manganese	EPA 200.7	0.02	mg/l
Mercury	EPA 245.2	0.001	mg/l

Mercury, low level	EPA 245.2	0.0002	mg/l
Molybdenum	EPA 200.7	0.005	mg/l
Nickel	EPA 200.7	0.03	mg/l
Potassium	EPA 200.7	1	mg/l
Selenium	EPA 270.2	0.005	mg/l
Selenium, ICAP	EPA 200.7	0.05	mg/l
Silicon	EPA 200.7	0.1	mg/l
Silver	EPA 200.7	0.005	mg/l
Sodium	EPA 200.7	1	mg/l
Strontium	EPA 200.7	0.1	mg/l
Thallium	EPA 279.2	0.1	mg/l
Tin	EPA 200.7	0.1	mg/l
Tungsten	EPA 200.7	0.25	mg/l
Uranium	ASTM D2907	0.01	mg/l
Vanadium	EPA 200.7	0.10	mg/l
Zinc	EPA 200.7	0.01	mg/l
Acidity as CaCO3	EPA 305.1	1	mg/l
Alkalinity, Total, HCO3, CO3, OH	EPA 310.1	1	mg/l
BACTERIA			
Fecal Coliform	MPN	1	col./100 ml
Fecal Coliform	MF	1	col./100 ml
Fecal Strep.	MPN	1	col./100 ml
Fecal Strep.	MF	1	col./100 ml
Total Coliform	MPN	1	col./100 ml
Total Coliform	MF	1	col./100 ml
Stand/Plate Count	MF	1	col./1 mls
Stand/Plate Count	Pour Plate	1	col./1 ml

BOD, 5 day	EPA 405.1	1	mg/l
Bromide	Potentiometer	0.1	mg/l
COD	EPA 410.1	1	mg/l
COD, Saline	EPA 410.3	1	mg/l
Chloride	EPA 325.3	1	mg/l
Color	EPA 110.2	1	Pt-Co
CYANIDE			
Amen.to chlor.	EPA 335.1	0.005	mg/l
Total manual	EPA 335.2	0.005	mg/l
Total auto. UV	EPA 335.3	0.005	mg/l
Weak Acid Diss.	ASTM	0.005	mg/l
Fluoride elec.	EPA 340.2	0.10	mg/l
Gross Alpha	EPA 900.0	1	pCi/l
Gross Beta	EPA 900.0	1	pCi/l
Hardness as CaCO3	EPA 130.2	1	mg/l
Hydroxide	EPA 310.1	1	mg/l
Iodide	EPA 345.1	0.1	mg/l
Magnesium	EPA 242.1	1	mg/l
NITROGEN			
Ammonia	EPA 350.3	0.1	mg/l
Nitrate+Nitrite	EPA 353.2	0.05	mg/l
Nitrite as N	EPA 354.1	0.05	mg/l
Total Kjeldahl	EPA 351.2	0.1	mg/l
OIL AND GREASE			
IR Spec.	EPA 413.2	1	mg/l
Gravimetric	EPA 413.1	1	mg/l
pH	EPA 150.1	0.1	std. units
Phenolics, dist.	EPA 420.2	0.01	mg/l

PHOSPHORUS			
Hydrolyzable	EPA 365.1	0.01	mg/l
Ortho	EPA 365.1	0.01	mg/l
Total	EPA 365.1	0.01	mg/l
Total organic	EPA 365.1	0.01	mg/l
Radium 226	EPA 903.0	1	pCi/l
Radium 228	EPA 904.0	1	pCI/l
RESIDUE			
Non-filt.(TSS)	EPA 160.2	1	mg/l
Total	EPA 160.3	1	mg/l
Filterable (TDS)	EPA 160.1	1	mg/l
Volatile (VSS)	EPA 160.4	1	mg/l
Resistivity	EPA 120.1	0.046	ohms/ cubic meter
Settleable Matter	EPA 160.5	1	mg/l
Spec. Cond. @ 25 C	EPA 120.1	0.1	umhos/cm
Specific Gravity		1.000	H2O=1.000
Sulfate	EPA 375.3	1	mg/l
SULFIDE			
Spec. ion elec.	EPA 376.1	0.04	mg/l
Meth.blue Color.	EPA 376.2	0.04	mg/l
Surfactants (MBAS)	Std. Methods	1	mg/l
TOC	EPA 415.1	2	mg/l
Turbidity	EPA 180.1	0.01	NTU

CHAPTER 8

GENERAL LABORATORY PRACTICES

1. Chemicals and reagents

All chemicals used for making reagents or standards are analytical reagent grade (AR) chemicals. Primary standards are used when required. Reagents are prepared and standardized against guaranteed primary standards. These reagents are restandardized and made fresh as required by their stability. Stock or working standards are checked regularly for signs of deterioration.e.g. discolorations, formation of precipitates, and comparison to independently prepared reference materials.

Primary standards are obtained from reliable sources, pretreated when necessary, accurately prepared in volumetric flasks and stored in containers that will not alter the particular reagent. Even with the use of AR grade chemicals, gases and solvents, determinate errors may still exist. In order to determine if reagent interferences exist, a method's blank is run whenever an analysis is made. If the interferences cannot be eliminated, the magnitude of the interference is considered when calculating the concentration of the specific constituent in the samples being analyzed. If the reagents and/or solvents contain substances that interfere with a particular determination, these reagents and/or solvents are replaced.

2. Glassware preparation

All glassware are washed in a warm detergent solution and thoroughly rinsed in tap water. They are then washed with 1:1 HNO_3 and rinsed three times with deionized water. This cleaning procedure is

sufficient for most analytical needs, but the individual procedures are referenced for more elaborate precautions taken against contamination of glassware.

In all volumetric work, boro-silicate glass is used except on rare occasions, like Boron determinations, storage of alkaline solutions and silica standards. Volumetric glassware, class A, is used in all precise measurements of volume.

3. Laboratory pure water

Distilled or demineralized water is used in the laboratory for dilution, preparation of reagent solutions and final rinsing of glassware. Because of the possibility of determinate errors caused by contaminated deionized water, the water's conductivity is continuously monitored automatically. Deionized water that is less than 1 micromhos/cm at 25 degrees C is considered excellent and is the maximum level acceptable for Energy Laboratories' use. The ion exchange cartridge is replaced regularly before is is completely exhausted. If the conductivity of the demineralized water exceeds 1 micromho/cm at 25 degrees C, the automatic monitor alerts the laboratory staff and the appropriate maintenance is taken to restore the water quality. Planned quality checks are made on a monthly basis, and a complete analysis is run on water including basic cations/anions and trace metals. These checks are documented and on file in the office.

CHAPTER 9

QUALITY ASSURANCE

INTERNAL QUALITY CONTROL CHECKS

1. On a daily basis:

-check and record temperatures of incubators, water baths, refrigerators, and ovens

-calibrate pH meter; use pH buffers only once and discard when through

-date reagents at the time of purchase and time of opening (reagents should not be used after the recommended shelf life is exceeded)

-check and record the pH and conductivity of laboratory pure water

-a standard reagent curve composed of a minimum of a reagent blank and three standards covering the concentration range of the samples is prepared. At least one of the standards is at or below the maximum contaminant level

-standard curves are verified with a minimum of a method blank, 2 standards within the range of the standard curve, and a known reference sample. Daily checks are required to be within 10 percent of the original curve.

-standard curves are verified by running an additional standard within the range of the standard curve every 20 samples. These must be within 10 percent of the original curve.

-duplicate samples are run every 10 samples to verify precision of the method. Checks must be within the control limits established

for each analysis. The criteria for duplicate sample acceptance are found in the appendix.

-spiked samples are run every 10 samples to determine sample interferences and to verify precision of the method. Checks must be within the control limits established for each analysis. (a sample is spiked with a known amount of a standard of that particular parameter. It is then analyzed and a % recovery of the original standard is calculated). The criteria for acceptance of spike recovery are found in the appendix.

-utilize cation/anion balance for further verification. The sigma of the total milliequivalents of the major anions and cations must not exceed 2.0.

-analyze known reference sample, EPA or ERA, every 20 samples to verify calibration. Each analysis of known reference must be within recommended limits set by EPA and / or ERA.

2. On a weekly basis

-class S weights are available, and are used to check accuracy of balances. These are recorded and documented in the quality assurance workbook.

3. On an annual basis, or more often if required

-balances are calibrated by an independent service company

-a certified thermometer is used to check other thermometers. New thermometers are checked and tagged against the certified thermometer.

-analyze split samples

-on-site evaluation of laboratory and records by the EPA designated certification officer.

-analyze state or EPA performance evaluation samples as required.

CHAPTER 10

REFERENCES

1. Handbook for Analytical Quality Control in Water and Wastewater Laboratories. Environmental Protection Agency, June 1972.

2. Standard Methods for the Examination of Water and Wastewater. 15th Edition, 1980. APHA-AWWA-WPCF.

3. Methods for Chemical Analysis of Water and Wastes. Environmental Protection Agency 600/4-79-020.

4. Annual Book of Standards Part 31 (water). American Society for Testing and Materials.

APPENDIX A

RESUMES OF PERSONNEL

JOHN M. STANDISH

LABORATORY DIRECTOR/ CHIEF CHEMIST

Experienced in the examination of many types of environmentally related samples including water, soil, coal and air pollutants.

EXPERIENCE

December 1981 to present - Chief Chemist for Energy Laboratories, Inc., Billings, Montana. Responsible for direction, training and supervision of the analytical laboratory staff. Involved in new procedural and equipment development, client relations, quality control, and report preparation at all branch laboratories.

August 1974 to December 1981 - Director of Chemical and Environmental Laboratory; Northern Testing Laboratories, Inc., Billings, Montana. Responsible for personnel training and supervision, laboratory schedules, client relations and methodology development. Chief areas of analysis were soils, water, coal, air pollution, and meteorological monitoring.

EDUCATION

B.S. in Biology; College of Great Falls; Great Falls, Montana 1973

PROFESSIONAL MEMBERSHIPS

American Society for Testing and Materials

Montana Mining Association

Montana Geological Society

Northwestern Mining Association

WILLIAM T. BROWN

LABORATORY MANAGER - GILLETTE BRANCH

Experienced in commercial fisheries management and analytical chemistry.

EXPERIENCE

July 1981 to present - Manager; Energy Laboratories, Inc., Branch Laboratory, Gillette, Wyoming. Responsible for routine analysis and quality control of water, natural gas and petroleum products. Involved in field on-site sampling and testing, meter calibrations, and supervision of branch laboratory staff.

November 1979 to July 1981 - Laboratory Technician; Energy Laboratories, Inc., Billings, Montana. Responsible for natural gas and petroleum products department of the lab including field natural gas testing. Also involved with various work in water and soil analysis including formal training in ion chromatography.

July 1977 to October 1979 - Fisheries Biologist; Water and Forests Department of the Government of Niger, Africa while in the Peace Corps. Responsible for developing fisheries management programs in a specific region including monitoring water quality by on-site testing during that period.

EDUCATION

B.S. in Fish and Wildlife Management; Montana State University; Bozeman, Montana.

FRANCIS M. BUBIS

MICROBIOLOGIST

Experienced in the examination of many types of environmentally related samples, including water, soil, and coal.

EXPERIENCE

April 1985 to present - Water Laboratory Supervisor; Energy Laboratories, Inc., Billings, Montana. Responsible for routine analysis and quality assurance procedures. Involved in new procedural development and instrumentation set up.

January 1984 to April 1985 - Finish Carpenter; High-Tech Construction and Properties, Inc., Billings, Montana.

April 1978 to January 1983 - Supervisor of Coal and Soil Laboratory; Northern Testing Laboratories, Inc., Billings, Montana. Responsible for routine analysis and quality assurance procedures.

EDUCATION

B.S. in Microbiology; Ohio State University; Columbus, Ohio 1974

RICHARD L. BROWN

PRESIDENT

Experienced in analytical chemistry and laboratory management.

EXPERIENCE

July 1978 to present - President and managing .officer; Energy Laboratories, Inc., Billings, Montana.

March 1970 to July 1978 - Laboratory Manager; Energy and Environmental Resource Consultants, Inc., Billings, Montana. Responsible for overall supervisicn of commercial laboratory. Areas of analytical experience include field brines, domestic waters, trace metals, microbiological contamination, core analysis, natural gas including H2S, RSH, COS, CS2, hydrocarbons, and inerts, refinery gases, refinery scales, and refined products. Has performed special research for sulfur plants and petroleum refineries. Experienced in field petroleum engineering work and petroleum reservoir engineering.

April 1955 to March 1970 - Assistant Laboratory Manager and Field Engineer; Yapuncich, Sanderson and Brown Laboratories. Supervised commercial laboratory. Made field measurements of subsurface pressure in oil and gas wells. Measured open flow potential of gas wells. Certified USDA meat analysis laboratory.

October 1951 to April 1955 - Manager; Chemical and Geological Laboratories of Texas. Managed branch laboratory involved in oil field core analysis. Responsible for overall supervision of engineers and technicians. Prepared estimates of reserves in petroleum reservoirs.

June 1948 to October 1951 - Chemist, Assistant Laboratory Supervisor; Chemical and Geological Laboratories of Texas. Chemical analysis of cores, water, crude oils, and natural gas.

EDUCATION

B.S. in Chemistry; University of Wyoming, Laramie, Wyoming 1948.

PROFESSIONAL MEMBERSHIPS

American Water Works Association Society of Petroleum Engineers
Montana Geological Society

EARL H. HOERGER

SENIOR ANALYTICAL CHEMIST

Experienced in chemical education and analytical chemistry.

EXPERIENCE

October 1981 to present - Analytical Chemist; Energy Laboratories, Inc., Billings, Montana. Responsible for special analytical projects and methods development. Areas of expertise include identification of unknown organic and inorganic materials, infrared spectroscopy, gas chromatography, scale and corrosion product analysis, crude oil and petroleum fuels analysis, and analysis of amine solutions. Repairs laboratory glassware with glass blowing equipment. Prepares and standardizes laboratory standard solutions.

January 1974 to October 1981 - Owner/Operator; Sage Research. Specialiing in special research projects and analytical chemicstry.

1971 to 1973 - Analytical Chemist; Yapuncich, Sanderson and Brown Laboratories, Billings, Montana. Oilfield water analysis, special projects, scale analysis, and analytical methods development.

1959 to 1971 - Professor of Chemistry; Rocky Mountain College, Billings, Montana.

1955 to 1959 - Associate Professor, Chemistry; Morningside College, Sioux City, Iowa.

1953 to 1955 - Assistant Professor, Chemistry; Talladega College, Talladega, Alabama.

1944 to 1945 - Research Assistant; California Institute of Technology, Pasadena, California. Chemistry of smokeless powder constituents.

EDUCATION

A.B. in Chemistry, Wabash College, Crawfordsville, Indiana 1944.

Ph.D. in Organic Chemistry, University of California 1955.

PROFESSIONAL MEMBERSHIPS

American Chemical Society

ROGER A. GARLING

LAB MANAGER - CASPER BRANCH

Experienced in ion exchange technology, water treatment technology - reverse electrodialysis chemical precipitation, flocculation and filtration, osmosis, hydrometalurgical process plant design and engineering, inorganic water quality analysis, source material license preparation/mining permit applications, radiological safety and monitoring, environmental air and water quality monitoring, in-situ leach oxidation processes, aquifer restoration processes, and personnel training and supervision.

EXPERIENCE

1984 to present - Branch Manager; Energy Laboratories, Inc., Casper, Wyoming. Responsible for client relations, direction and training of the technical and office staff.

1981 to 1984 - Operations Superintendent; Leuenberger In-Situ Project, UNC Teton Exploration Drilling, inc. The project involved development and implementation of a uranium in-situ leach aquifer restoration and decontamination/decommissioning of the associated pilot plant.

November 1979 to February 1981 - Process engineer; Leuenberger In-Situ Project, UNC Teton Exploration Drilling, Inc. The project involved pilot operation of a bicarbonate lixiviant in-situ uranium leach process.

January 1977 to October 1979 - Senior Plant Chemist; Wyoming Mineral Corporation, Lakewood, Colorado. The position involved an analytical laboratory operation designed to support process and environmental requirements of an 800gpm in-situ uranium mine.

April 1976 to January 1977 - Senior Laboratory Technician; Wyoming Mineral Corporation, Lakewood, Colorado.

EDUCATION

University of Utah, Salt Lake City, Utah

Decision Making and Problem Solving, Westinghouse Management

Engineering Management, American Management Association

Fundamentals of Management and Organization, Eastern Wyoming College

Uranium Technology, Colorado School of Mines

DONALD O. PHILLIPS

OPERATIONS MANAGER - CASPER BRANCH

Experienced in water and air chemical analysis.

EXPERIENCE

November 1984 to present - Operations Manager; Energy Laboratories, Inc., Casper, Wyoming. Responsible for supervision and training of technical staff.

April 1982 to November 1984 - Environmental Technician; Minerals Co., Green River, Wyoming. Responsible for monitoring of ambient air quality, surface water, ground water, and site generated emmission of airborne particulates, SO2, and NOx. Also testing of all emmission sources required by state and federal agencies. Soil reclamation and wildlife surveys.

June 1981 to April 1982 - Plant Chemist; O.P.I. Western-Joint Venture, Casper, Wyoming. Directly involved with wellfield, plant, and laboratory construction design. Responsible for administration of the on site laboratory facility. Also responsible for production and environmental samples analyses, data evaluation, and reporting.

August 1978 to April 1981 - Senior Chemical Technician; Wyoming Mineral Corporation, Buffalo, Wyoming. Daily analysis of process and environmental samples, technical guidance to lower classified personnel, and equipment maintenance and calibration. When promoted to Plant Chemist, responsibilities included supervision of the laboratory personnel, training of laboratory technicians, data evaluation for process and environmental sectors, ordering of analytical equipment and chemicals, and developing analytical procedures.

EDUCATION

Akron University, Akron, Ohio 1966-67.

A.I.M.E. Seminar Concerning In-Situ Uranium Mining Technology 1978, 1979.

A.C.S. Audio Course, Atomic Absorption Spectroscopy.

WILLIAM WATSON

ANALYTICAL CHEMIST

Experienced in the examination of many types of environmentally related samples, including soil, coal, and water.

EXPERIENCE

August 1983 to present - Laboratory Technician/Supervisor; Energy Laboratories, Inc., Billings, Montana. Responsible for supervision of soils staff, routine analysis, and quality control. Chief areas of analysis include soil (overburden and agricultural), coal, feeds, and vegetation.

June 1979 to June 1983 - Laboratory Technician; Northern Testing Laboratories, Inc., Billings, Montana. Principally responsible for soil and coal analysis. Involved in operating and calibration of meteorological systems.

EDUCATION

B.S. in Science, Major Geology, Montana State University, Bozeman, Montana 1977.

DONNA M. DOWNEY

ANALYST

Experienced in the examination of environmentally related samples, including soil, water, and feed.

EXPERIENCE

August 1984 to present - Technician/Office Manager; Energy Laboratories, Inc., Billings, Montana. Primarily responsible for routine analysis and quality control of the Microbiology Laboratory. Currently certified with the State of Montana for bacteriological analysis of drinking water. Also responsible for monitoring all incoming samples and outgoing reports.

January 1984 to July 1984 - non-related work experience (insurance)

July 1976 to September 1983 - Technician; Montana Testing Laboratories, Inc., Great Falls, Montana. Involved in routine analysis and quality control in soil, water, and feed laboratories. Certified with the state of Montana for bacteriological analysis of drinking water, December 1979 to December 1982.

EDUCATION

Special training class for bacteriological certification; Montana Department of Health and Environmental Sciences 1979

Class for bacteriological certification; Montana Department of Health and Environmental Sciences 1985

PROFESSIONAL MEMBERSHIPS

American Water Works Association

APPENDIX B

PRECISION ACCEPTANCE CRITERIA

PARAMETER	ROUTINE DETECTION LIMIT, mg/l	RANGE OF SAMPLE CONCENTRATION, mg/l	ACCEPTABLE DIFF. BETWEEN DUPS., mg/l
Aluminum	0.1	0.1-0.5	0.1
		0.5-5.0	0.3
		5.0-50	2
Arsenic	0.005	0.005-0.025	0.002
		0.025-0.250	0.03
Barium	0.1	0.1-0.5	0.1
		0.5-5.0	0.2
		5.0-50	2
Beryllium	0.005	0.005-0.025	0.002
		0.025-0.250	0.005
		0.250-3.0	0.02
Boron	0.1	0.1-0.5	0.1
		0.5-5.0	0.2
		5.0-50	1.0
Cadmium	0.001	0.001-0.005	0.002
		0.005-0.050	0.005
		0.050-0.50	0.02
Calcium	1	1-5	2
		5-50	5
		50-500	25
		500-5000	100
Chromium	0.02	0.02-0.10	0.04
		0.10-1.0	0.2
		1.0-10	2.0
Cobalt	0.01	0.01-0.05	0.02
		0.05-0.5	0.10
		0.5-5.0	0.5
Copper	0.01	0.01-0.05	0.02
		0.05-0.5	0.1
		0.5-5.0	1.0
		5.0-50	5
Gold	0.01	0.01-0.1	0.02
		0.1-1.0	0.1
		1.0-10	1.0

PARAMETER	ROUTINE DETECTION LIMIT, mg/l	RANGE OF SAMPLE CONCENTRATION, mg/l	ACCEPTABLE DIFF. BETWEEN DUPS., mg/l
Iron	0.03	0.03-0.2	0.06
		0.2-2.0	0.3
		2.0-30	2
		30-300	5
Lead	0.01	0.01-0.05	0.02
		0.05-0.5	0.05
		0.5-5.0	0.5
Lithium	0.01	0.01-0.05	0.02
		0.05-0.5	0.1
		0.5-5.0	1.0
		5.0-50	5
Magnesium	1	1-5	2
		5-50	5
		50-500	25
		500-5000	100
Manganese	0.02	0.02-0.1	0.04
		0.1-1.0	0.2
		1.0-10	2.0
		10-100	10
Mercury	0.001	0.001-0.005	0.002
		0.005-0.050	0.010
		0.050-0.50	0.010
Molybdenum	0.005	0.005-0.025	0.010
		0.025-0.25	0.04
		0.25-2.5	0.4
Nickel	0.03	0.03-0.15	0.06
		0.15-1.5	0.3
		1.5-15	3
Potassium	1	1-5	2
		5-50	5
		50-500	25
		500-5000	100
Selenium	0.005	0.005-0.025	0.002
		0.025-0.250	0.03
Silicon	0.1	0.1-0.5	0.2
		0.5-5.0	1.0
		5.0-50	5
		50-500	25

PARAMETER	ROUTINE DETECTION LIMIT, mg/l	RANGE OF SAMPLE CONCENTRATION, mg/l	ACCEPTABLE DIFF. BETWEEN DUPS., mg/l
Silver	0.005	0.005-0.025	0.005
		0.025-0.25	0.04
		0.25-2.5	0.4
Sodium	1	1-5	2
		5-50	5
		50-500	25
		500-5000	100
Strontium	0.1	0.1-0.5	0.2
		0.5-5.0	0.5
		5.0-50	2.5
Vanadium	0.1	0.1-0.5	0.2
		0.5-5.0	1.0
		5.0-50	5.0
Zinc	0.01	0.01-0.05	0.02
		0.05-0.5	0.1
		0.5-5.0	1.0
Acidity	1	1-100	3
		100-500	9
Alkalinity	1	1-100	3
		100-500	9
		500-5000	40
Bromide	0.1	0.1-0.5	0.2
		0.5-5.0	0.5
		5.0-50	5.0
C.O.D.	1	1-15	4
		15-50	6
		50-200	10
		200-1000	20
Chloride	1	1-5	2
		5-50	5
		50-500	25
		500-5000	100
Cyanide	0.005	0.005-0.025	0.003
		0.025-0.25	0.02
		0.25-2.5	0.1
		2.5-25	1.0

PARAMETER	ROUTINE DETECTION LIMIT, mg/l	RANGE OF SAMPLE CONCENTRATION, mg/l	ACCEPTABLE DIFF. BETWEEN DUPS., mg/l
Fluoride	0.10	0.10-0.50	0.07
		0.50-5.0	0.17
		5.0-50	0.4
Hardness	1	1-5	2
		5-50	5
		50-500	25
		500-5000	100
Iodide	0.1	0.1-0.5	0.2
		0.5-5.0	0.5
		5.0-50	3.0
N-Ammonia	0.1	0.1-0.5	0.2
		0.5-5.0	0.5
		5.0-50	4
		50-500	15
N-Nitrate	0.05	0.05-0.25	0.02
		0.25-2.5	0.1
		2.5-25	0.6
N-Nitrite	0.05	0.05-0.25	0.02
		0.25-2.5	0.1
		2.5-25	0.6
N-TKN (kjeldahl)	0.1	0.1-0.5	0.2
		0.5-5.0	0.4
		5.0-50	4
		50-500	25
Oil & Grease	1	1-15	1
		15-30	3
		30-100	6
pH	std. units	1-13 S.U.	0.1
Phenolics	0.01	0.01-0.05	0.02
		0.05-0.5	0.05
		0.5-5.0	0.5
Phosphorus	0.01	0.01-0.05	0.02
		0.05-0.50	0.05
		0.50-5.0	0.2
		5.0-50	1

PARAMETER	ROUTINE DETECTION LIMIT, mg/l	RANGE OF SAMPLE CONCENTRATION, mg/l	ACCEPTABLE DIFF. BETWEEN DUPS., mg/l
Residue, TSS	1	1-10	2
		10-50	5
		50-500	10
		500-5000	50
Residue, TDS	1	1-10	2
		10-50	5
		50-500	25
		500-5000	100
		5000-50000	500
Specific Cond.	umhos/cm	5-500	10
		500-5000	150
		5000-50000	500
Sulfate	1	1-50	5
		50-500	25
		500-2000	50
		2000-5000	200
Sulfide	0.04	0.04-0.20	0.03
		0.20-2.0	0.2
		2.0-20	2
TOC	2	2-10	2
		10-50	4
		50-100	6
Turbidity	N.T.U.	0.01-1.0	0.05
		1.0-10	1
		10-50	5
		50-500	20
		500-1000	50
		1000-3000	100
		3000 plus	200

APPENDIX C

ACCURACY ACCEPTANCE CRITERIA

PARAMETER	ACCEPTABLE SPIKE RECOVERY, %
Aluminum	85-115
Antimony	85-115
Arsenic	85-115
Barium	90-110
Beryllium	90-110
Boron	85-115
Cadmium	85-115
Calcium	90-110
Chromium	85-115
Cobalt	85-115
Copper	90-110
Gold	85-115
Iron	90-110
Lead	90-110
Lithium	85-115
Magnesium	90-110
Manganese	90-110
Mercury	85-115
Molybdenum	85-115
Nickel	90-110
Potassium	90-110
Selenium	85-115
Silicon	85-115
Silver	85-115
Sodium	90-110
Strontium	90-110
Thallium	90-110
Tin	90-110
Tungsten	90-110
Vanadium	90-110
Zinc	85-115
Bromide	85-115
C.O.D.	90-110
Chloride	90-110
Cyanide	90-110
Fluoride	90-110
Iodide	85-115
N-Ammonia	90-110
N-Nitrate	90-110
N-Nitrite	90-110
N-TKN (kjeldahl)	85-115
Phenolics	90-110
Phosphorus	90-110
Sulfate	85-115
Sulfide	85-115
TOC	90-110

EXHIBIT H-6.2

RESULTS OF LABORATORY ANALYSES FOR QUALITY ASSURANCE PROGRAM

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

LABORATORY REPORT

To: HKM Associates (1) Lab No.: 87-2604dup
Address: PO Box 31318 Date: 3-24-87 tab
Billings, Montana 59107
ATTN: Jim McGill

QUALITY ASSURANCE - DUPLICATE ANALYSIS

Clark Well
Sampled 3-12-87 @ 1030
Samples Submitted 3-13-87

CONSTITUENT	mg/l	
Carbonate	0	
Potassium	3	
Sodium	14	
Calcium	81	
Magnesium	20	
Sulfate	25	
Chloride	8	
Alkalinity as CaCO3	261	
Specific Conductance @ 25°C	566	umhos/cm
pH	7.5	s.u.
Ammonia as NH3	<0.1	
Nitrate + Nitrite as N	1.68	
Phosphorus as P	0.03	
Fluoride	0.14	
METALS (dissolved):		
Aluminum	<0.02	
Antimony	0.01	
Arsenic	<0.005	
Barium	<0.10	
Beryllium	<0.005	
Boron	<0.10	
Cadmium	<0.001	
Chromium	<0.02	
Copper	<0.01	
Iron	<0.05	
Lead	<0.02	
Manganese	<0.02	
Mercury	<0.001	
Nickel	<0.01	
Selenium	0.007	
Silver	<0.005	
Thallium	<0.01	
Zinc	0.02	

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

LABORATORY REPORT

To: HKM Associates (1) Lab No.: 87-2605sp
Address: PO Box 31318 Date: 3-24-87 tab
Billings, Montana 59107
ATTN: Jim McGill

QUALITY ASSURANCE - SPIKED ANALYSIS

Leaverton Well
Sampled 3-11-87 @ 1622
Samples Submitted 3-13-87

CONSTITUENT	% Spike Recovery
Potassium	110
Sodium	110
Calcium	103
Magnesium	110
Sulfate	95
Chloride	93
Ammonia as NH3	109
Nitrate + Nitrite as N	100
Phosphorus as P	98
Fluoride	95
METALS (dissolved):	
Aluminum	112
Antimony	93
Arsenic	105
Barium	106
Beryllium	108
Boron	96
Cadmium	100
Chromium	108
Copper	104
Iron	99
Lead	91
Manganese	98
Mercury	101
Nickel	93
Selenium	100
Silver	78
Thallium	108
Zinc	104

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325

LABORATORY REPORT

To: HKM Associates
Address: PO Box 31318
Billings; Montana 59107
ATTN: Jim McGill

Lab No.: 87-2604 -07
Date: 3-24-87 tab

SPECIAL WATER ANALYSIS

This report represents the results of a reference water sample tested with this set of samples.

CONSTITUENT	RESULT, mg/l	TARGET RANGE, m/gl
Potassium	4.92	4.17 - 5.71
Sodium	20.9	17.8 - 22.3
Calcium	21.5	17.5 - 22.2
Magnesium	5.30	4.18 -5.62
Ammonia as NH3	0.27	0.23 - 0.33
Nitrate + Nitrite as N	1.49	1.29 - 1.55
Phosphorus as P	0.22	0.05 - 0.25
Fluoride	0.21	0.19 - 0.27
Aluminum	0.519	0.423 - 0.623
Antimony	0.020	0.008 - 0.031
Arsenic	0.027	0.020 - 0.032
Barium	1.05	0.845 - 1.15
Beryllium	0.100	0.086 - 0.112
Boron	1.01	0.845 - 1.15
Cadmium	0.026	0.020 - 0.028
Chromium	0.100	0.078 - 0.119
Copper	0.099	0.088 - 0.113
Iron	0.088	0.083 - 0.119
Lead	0.102	0.083 - 0.116
Manganese	0.099	0.088 - 0.111
Mercury	0.0020	0.0014 - 0.0022
Nickel	0.097	0.084 - 0.116
Selenium	0.022	0.015 - 0.036
Silver	1.01	0.910 - 1.07
Thallium	0.24	0.014 - 0.028
Zinc	0.098	0.086 - 0.115